Appendix A – Exposure/Response Matrices

Introduction

This appendix provides the exposure/response matrices for the HCP species potentially affected by the various fish passage subactivity types addressed in this white paper. The list of HCP species addressed in this white paper series includes a number of marine species that are either: (1) not affected by the subactivity types addressed in this paper, or (2) are exposed but to effects explicitly addressed in other white papers (e.g., construction and operation of tidegates). In the interest of readability, the matrices were developed only for those HCP species that may experience potential stressor exposure. These include the following:

Common Name	Series Matrix Number	Matrix in this Appendix
Chinook salmon	A-1	Yes
Coho salmon	A-2	Yes
Chum salmon	A-3	Yes
Pink salmon	A-4	Yes
Sockeye salmon	A-5	Yes
Steelhead	A-6	Yes
Coastal cutthroat trout	A-7	Yes
Redband trout, westslope cutthroat trout	A-8	Yes
Bull trout, Dolly Varden	A-9	Yes
Pygmy whitefish	A-10	Yes
Olympic mudminnow	A-11	Yes
Lake chub, leopard and Umatilla dace, margined sculpin, mountain sucker	A-12	Yes
Pacific lamprey, river lamprey, Western brook lamprey	A-13	Yes
Green sturgeon, white sturgeon	A-14	Yes
Eulachon, longfin smelt	A-15	*No*
Pacific sand lance, surf smelt	A-16	*No*
Pacific herring	A-17	*No*
Lingcod	A-18	*No*
Pacific cod, Pacific hake, walleye pollock	A-19	*No*
Black, bocaccio, brown, canary, China, copper, greenstriped, quillback, redstripe, tiger, widow, yelloweye, and yellowtail rockfish	A-20	*No*
Olympia oyster	A-21	*No*
Northern abalone	A-22	*No*
Newcomb's littorine snail	A-23	*No*
Giant Columbia River limpet, Great Columbia River spire snail	A-24	Yes
California floater (mussel), Western ridged mussel	A-25	Yes

Table A-1. HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual-decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg and alevin survival. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect egg and alevin survival. May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg and alevin survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg, alevin, and juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (depending on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removal/ replacement/ retrofit of a structure for fish passage purposes is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	<u>Design</u>: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg and alevin survival. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual-decadal (depending on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. <u>Juveniles</u>: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual-decadal (depending on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and alevin life-history stages. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival during egg and alevin life-history stages. May affect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality or injury from entrainment. <u>Juveniles</u>: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Decreased survival due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during egg and alevin life-history stages. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	During construction	Short-term	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance activities	Short-term	Interannual–decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Decreased survival due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	<u>Eggs and alevins</u>: Decreased incubation success. <u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. <u>Juveniles</u>: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-1 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	<u>All exposed life-history stages</u>: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	<u>All exposed life-history stages</u>: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-2. HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles</u>: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removal/ replacement/ retrofit of a structure for fish passage purposes is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removal/ replacement/ retrofit of a structure for fish passage purposes is expected to be limited in extent in comparison to initial installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	<u>Design</u>: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	During construction	Short-term	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During construction	Short-term	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate the potential effects of expanded fish passage on eutrophication. Reduce anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance activities	Short-term	Interannual-decadal (depending on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance activities	Short-term	Interannual–decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-2 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-3. HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs and alevins, juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential redd scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Stress and behavioral modifications by migrating juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles</u>: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Adults	<u>Eggs and alevins:</u> Decreased survival due to winter ice formation and scour. <u>Adults</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability for adult migration and spawning, and juvenile holding and migration	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can affect migration rates, predation exposure, and other parameters, affecting survival, growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation)	Permanent	Continuous				

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles: Altered habitat complexity may alter migratory corridors and holding areas, leading to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by juveniles exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate the potential for fish passage projects to contribute to eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual-decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, and reduced spawning and habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in altered migratory and holding habitat complexity. This may increase predation exposure and alter migratory behavior, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation)	Permanent	Continuous				

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by migrating juveniles exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in migratory habitat structure and habitat suitability, and reduced spawning habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased migration habitat suitability. This may alter migration timing and/or increase predation exposure leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and adult migration)	Permanent	Continuous				

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. <u>Juveniles</u>: Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	<u>Adults and juveniles</u>: Decreased availability of suitable migration holding habitats may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by migrating juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance activities	Short-term	Interannual–decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and migration holding habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can alter migratory pathways and behavior. This may delay or speed migration unfavorably, and/or increase predation exposure, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and adult migration)	Permanent	Continuous				

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable migration holding habitats may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-3 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-4. HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by migrating juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability for adult migration and spawning, and juvenile holding and migration	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can affect migration rates, predation exposure, and other parameters, affecting survival, growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation)	Permanent	Continuous				

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles: Altered habitat complexity may alter migratory corridors and holding areas, leading to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by juveniles exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect survival, growth, and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential effects of increased passage on eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, and reduced spawning and habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in altered migratory and holding habitat complexity. This may increase predation exposure and alter migratory behavior, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation)	Permanent	Continuous				

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by migrating juveniles exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance activities	Short-term	Interannual–decadal (dependent on maintenance frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in migratory habitat structure and habitat suitability, and reduced spawning habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased migration habitat suitability. This may alter migration timing and/or increase predation exposure leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and adult migration)	Permanent	Continuous				

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable migration holding habitats may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of eggs, alevins, juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at egg, alevin, and juvenile life-history stages. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by migrating juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival of incubating eggs and alevins. May affect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and alevins. May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require a TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs and alevins. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and migration holding habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can alter migratory pathways and behavior. This may delay or speed migration unfavorably, and/or increase predation exposure, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and adult migration)	Permanent	Continuous				

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable migration holding habitats may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-4 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-5. HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	<u>Design</u>: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate..	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modifications.		See effects for related stressors under Water Quality Modifications.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Decreased survival due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	<u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	<u>Eggs and alevins</u>: Decreased incubation success. <u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modifications.		See effects for related stressors of altered dissolved oxygen under Water Quality Modifications.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-5 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-6. HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Reduce anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthonous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality or injury from entrainment. <u>Juveniles</u>: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Decreased survival due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

Table A-6 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Steelhead Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-7. HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, riparian modification resulting from removing/ replacing/ retrofitting structures for fish passage is expected to be limited in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in comparison to initial installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	<u>Design</u>: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized <u>Juveniles</u>: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality or injury from entrainment. <u>Juveniles</u>: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Decreased survival due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-7 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Cutthroat Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-8. HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill) to long-term, dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, the extent of riparian modification resulting from structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modifications.		See effects for related stressors under Water Quality Modifications.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modifications								

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modifications.		See effects for related stressors of altered dissolved oxygen under Water Quality Modifications.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. <u>Juveniles</u>: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-8 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Bull Trout and Dolly Varden.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-9. HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, the extent of riparian modification resulting from structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in extent in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults			

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by structure removal/replacement/retrofitting for fish passage purposes is expected to be limited in comparison to initial installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and alevins; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of alevins and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and alevins; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-9 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Westslope Cutthroat and Redband Trout.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-10. HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, the extent of riparian modification resulting from structure removal/replacement retrofitting for fish passage purposes is expected to be limited in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults			

Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and larvae, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized <u>Juveniles</u>: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and larval mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs/larvae: Decreased incubation success due to egg sedimentation as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and larvae, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs/larvae: Decreased incubation success due to smothering of eggs by fine sediments as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults	Eggs and larvae: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and larvae, as well as adult spawning productivity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Establish a capture and handling protocol appropriate for whitefish.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and larvae; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.

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Table A-10 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-11. HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Juveniles and adults: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All expose life-history stages:</u> Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, the extent of riparian modification resulting from structure removal/ replacement/ retrofit for fish passage purposes is expected to be limited in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat. However, the extent of aquatic vegetation modification caused by structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows do not exhibit migratory behavior.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable foraging, resting, and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish ladder/fishway development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Flow bypass, fish handling, and channel rewatering	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Construction/maintenance dredging	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Water Quality Modifications								
		n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish ladder/fishway development. Exposure to water quality related stressors is unlikely to occur.
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish ladder/fishway development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered stream bank and shoreline stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered allochthonous inputs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater–surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Aquatic Vegetation Modifications								
	Altered autochthonous production	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish ladder/fishway development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish ladder/fishway development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered flow regime	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered substrate composition	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater-surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows are non-migratory species occurring only in low gradient habitats unsuitable for fish ladder/fishway development.
	Modified upstream transport of allochthonous nutrients	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for roughened channel development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Flow bypass, fish handling, and channel rewatering	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Construction/maintenance dredging	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Water Quality Modifications								
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for roughened channel development. Exposure to water quality related stressors is unlikely to occur.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for roughened channel development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered stream bank and shoreline stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered allochthonous inputs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater–surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for roughened channel development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for roughened channel development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered flow regime	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered substrate composition	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater-surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows are non-migratory species occurring only in low gradient habitats unsuitable for roughened channel development.
	Modified upstream transport of allochthonous nutrients	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Modified downstream transport of wood, sediment and organic material	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish passage weir development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Flow bypass, fish handling, and channel rewatering	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Construction/maintenance dredging	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Water Quality Modifications								
		n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish passage weir development. Exposure to water quality related stressors is unlikely to occur.

Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish passage weir development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered stream bank and shoreline stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered allochthonous inputs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater–surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Aquatic Vegetation Modifications								
	Altered autochthonous production	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish passage weir development. Exposure to these submechanisms and related stressors is unlikely to occur. May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows occur only in low gradient habitats unsuitable for fish passage weir development. Exposure to these submechanisms and related stressors is unlikely to occur.
	Altered flow regime	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered substrate composition	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater-surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows are non-migratory species occurring only in low gradient habitats unsuitable for fish passage weir development.
	Modified upstream transport of allochthonous nutrients	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Modified downstream transport of wood, sediment and organic material	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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Table A-11 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows do not occur in habitats suitable for trap and haul operations and do not exhibit migratory behavior.
	Accidental introduction of toxic substances	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Ecosystem Fragmentation								
	Alteration of migratory corridor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Olympic mudminnows do not occur in habitats suitable for trap and haul operations and do not exhibit migratory behavior.
	Passage barriers	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-12. HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. Cyprinids such as dace, chub, and suckers are hearing specialist species which have been demonstrated to be sensitive to auditory masking and hearing threshold effects.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses during construction where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, the extent of riparian modification resulting from structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during juvenile rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults			

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. However, the extent of aquatic vegetation modification caused by structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter juvenile behavior; may affect juvenile growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. Cyprinids such as dace, chub, and suckers are hearing specialist species which have been demonstrated to be sensitive to auditory masking and hearing threshold effects.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults		Avoid disturbance of vegetation along stream.	May affect survival of eggs and larvae, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. Cyprinids such as dace, chub, and suckers are hearing specialist species which have been demonstrated to be sensitive to auditory masking and hearing threshold effects.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and larval mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs/larvae: Decreased incubation success due to egg sedimentation as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and larvae, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: o Rupture of egg membrane. o Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. o Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. o Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. Cyprinids such as dace, chub, and suckers are hearing specialist species which have been demonstrated to be sensitive to auditory masking and hearing threshold effects.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased survival due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs/larvae: Decreased incubation success due to smothering of eggs by fine sediments as described for related stressor responses under Water Quality Modifications. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults	Eggs and larvae: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and larvae, as well as adult spawning productivity.

Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may be denied the ability to migrate downstream in certain circumstances. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at juvenile life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Dace, chub, and sculpin are not expected to be the subject of routine trap and haul operations, however incidental exposure to trap and haul operations may occur. The likelihood of stressor exposure is considered to be discountable however. Mountain sucker: Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Establish an appropriate capture and handling protocol for mountain sucker.	Dace, chub, and sculpin: The potential effects of this sumbechanism are considered discountable. Mountain sucker: May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and larvae; Juveniles; Adults	Dace, chub, and sculpin are not expected to be the subject of trap and haul operations, however some potential for exposure to infrequent short-term water quality effects could occur. Should exposure occur, these stressors may impose short-term effects on survival, growth, and fitness. All exposed life history stages (mountain sucker only): Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	Dace, chub, and sculpin: May affect survival, growth, and fitness across all life history stages. Sucker: May cause direct injury or mortality, may affect survival, growth and fitness.

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Table A-12 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Leopard Dace, Umatilla Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages (mountain sucker only): Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	Dace, chub, and sculpin: No effect. Mountain sucker: May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages (mountain sucker only): Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

Table A-13. HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Effects of underwater noise on lampreys are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Transforming adults; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	Effects of underwater noise on lampreys are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Mortality, injury, or stress from capture, handling, and relocation. Egg and amocoetes relocation is impractical, likely leading to mortality. Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of transforming adults and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults	Eggs and amocoetes, transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when transforming adults are present.	May cause direct mortality or injury at transforming adult life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and amocoetes life-history stages; may affect transforming adult growth and fitness; may affect adult spawning productivity
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential decreased egg incubation success and amocoetes survival due to turbidity exposure and substrate disturbance. Transforming adults: Stress and behavioral modifications by rearing transforming adults exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at transforming adult life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	n/a	n/a	n/a	Lamprey are not dependent on invertebrates for prey. Therefore this stressor will have no effect.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential decreased egg incubation success and amocoetes survival due to water loss and stranding. Transforming adults: Barrier to migration, loss of habitat accessibility, stranding, migration delay, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at transforming adult life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Direct injury or mortality from dredging entrainment. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury of eggs and amocoetes. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Decreased survival due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Transforming adults and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses during construction where practicable.	May affect transforming adult survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Turbidity sufficient to cause burial may lead to decreased survival of eggs and amocoetes. Transforming adults and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating Eggs and amocoetes. May affect transforming adult growth and fitness and adult productivity and spawning success.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of transforming adults and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and amocoetes; Transforming adults; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects across all life-history stages. However, the extent of riparian modification resulting from structure removal/ replacement retrofitting for fish passage purposes is expected to be limited in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness during transforming adult rearing for intermediate-term period.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and amocoetes; Transforming adults; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Amocoetes			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Amocoetes; Transforming adults; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and amocoetes; Adults			

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Amocoetes	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of transforming adults. However, the extent of aquatic vegetation modification caused by structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May alter transforming adult behavior; may affect transforming adult growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Amocoetes			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and amocoetes survival. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat suitability during migration, increasing predation exposure and stress. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, amocoetes, and transforming adult life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and transforming adult rearing)	Permanent	Continuous				

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Transforming adults; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Transforming adults: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Transforming adults may be denied the ability to migrate downstream in certain circumstances. Transforming adults may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at transforming adult life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Amocoetes;	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of amocoetes and transforming adults. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Transforming adults; Adults	Adults and transforming adults: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Effects of underwater noise on lampreys are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Transforming adults; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	Effects of underwater noise on lampreys are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of transforming adults and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults	Eggs and amocoetes, transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May cause direct mortality or injury at transforming adult life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and amocoetes life-history stages; may affect transforming adult growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect transforming adult growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential decreased egg incubation success and amocoetes survival due to turbidity exposure and substrate disturbance. Transforming adults: Stress and behavioral modifications by rearing transforming adults exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at transforming adult life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	n/a	n/a	n/a	Lamprey are not dependent on invertebrates for prey. Therefore this stressor will have no effect.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Direct injury or mortality from dredging entrainment. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect transforming adult growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Transforming adults; Adults	Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of Eggs and amocoetes. Transforming adults and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating Eggs and amocoetes. May affect transforming adult growth and fitness and adult productivity and spawning success.

Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect transforming adult survival and fitness. May affect adult survival and spawning productivity.
		Altered nutrient cycling	During and following discharge events	Long-term to permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate potential for increased passage to adversely affect eutrophication. Address anthropogenic sources of nutrient pollution to compensate.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and amocoetes; Transforming adults; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and amocoetes; Transforming adults; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Amocoetes		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect transforming adult survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults		Encourage project designs that limit permanent alteration of habitat features.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.

Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and amocoetes; Adults		Avoid disturbance of vegetation along stream.	May affect survival of Eggs and amocoetes, transforming adult survival, growth, and fitness, and adult survival and spawning productivity.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Amocoetes	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Amocoetes; Transforming adults; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and amocoetes survival. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat suitability during migration, increasing predation exposure and stress. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, amocoetes, and transforming adult life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and transforming adult rearing)	Permanent	Continuous				

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Transforming adults; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized <u>Transforming adults</u>: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Transforming adults may be denied the ability to migrate downstream in certain circumstances. Transforming adults may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. <u>Adults</u>: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. <u>All exposed life-history stages</u>: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect survival, growth, and fitness at transforming adult life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Amocoetes	<u>All exposed life-history stages</u>: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of amocoetes and transforming adults. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and amocoetes; Transforming adults; Adults	<u>All life-history stages</u>: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Effects of underwater noise on lampreys are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Transforming adults; Adults	<u>All exposed life-history stages</u>: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance-causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults; Adults	<u>All life-history stages</u>: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	Effects of underwater noise on lampreys are unknown.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and transforming adults</u>: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of transforming adults and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults	<u>Eggs and amocoetes, transforming adults</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when transforming adults are present.	May cause direct mortality or injury at transforming adult life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes</u>: Potential egg scour and/or sedimentation, resulting in decreased incubation success. <u>Transforming adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and amocoetes life-history stages; may affect transforming adult growth and fitness; may affect adult spawning productivity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect transforming adult growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential decreased egg incubation success and amocoetes survival due to turbidity exposure, burial, and substrate disturbance. Transforming adults: Stress and behavioral modifications by rearing transforming adults exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at transforming adult life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	n/a	n/a	n/a	Lamprey are not dependent on invertebrates for prey. Therefore this stressor will have no effect.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Barrier to migration, loss of habitat accessibility, stranding, migration delay, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at transforming adult life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes</u>: Direct injury or mortality from dredging entrainment. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	Egg and amocoetes mortality or injury is highly likely if exposure occurs. May affect transforming adult growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes:</u> Decreased survival due to winter ice formation and scour. <u>Transforming adults</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and transforming adults</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect transforming adult survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of Eggs and amocoetes. <u>Transforming adults and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating Eggs and amocoetes. May affect transforming adult growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	<u>All expose life-history stages:</u> Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes:</u> Decreased survival due to winter ice formation and scour. <u>Transforming adults</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and transforming adults</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.

Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs/amocoetes:</u> Decreased incubation and rearing success due to egg sedimentation as described for related stressor responses under Water Quality Modifications. <u>Transforming adults:</u> Decreased refuge habitat availability, leading to increased competition and resulting effects on survival. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Amocoetes	<u>Amocoetes:</u> Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect ammocoete survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Amocoetes; Transforming adults; Adults	<u>Amocoetes</u>: Decreased availability of suitable rearing habitat, reduced food web productivity, with resulting effects on survival, growth, and fitness. <u>Transforming adults:</u> Decreased refuge habitat availability with resulting effects on survival. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	<u>Eggs and amocoetes</u>: Decreased incubation and rearing success. <u>Transforming adults and adults</u>: Decreased availability of thermal refuge habitat, limiting transforming adult survival, growth, and fitness. May limit adult survival and spawning productivity. <u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of Eggs and amocoetes, transforming adult survival, growth, and fitness, and adult survival and spawning productivity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Amocoetes	Amocoetes: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect ammocoete growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Amocoetes;	Amocoetes: Reduced availability of suitable rearing habitats, leading to effects on survival, growth and fitness.		May affect ammocoete survival, growth and fitness.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and amocoetes survival. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat suitability during migration, increasing predation exposure and stress. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, amocoetes, and transforming adult life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and transforming adult rearing)	Permanent	Continuous				

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Transforming adults; Adults	Roughened channels will generally improve the condition of this submechanism. However, designs that are poorly conceived may create unintentional passage barriers over time. Should this occur, the following effects may be realized. Transforming adults: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Transforming adults may be denied the ability to migrate downstream in certain circumstances. Transforming adults may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review roughened channel designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at transforming adult life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for fish passage listed above.	May affect survival, growth, and fitness of amocoetes and transforming adults. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Transforming adults; Adults	Adults and transforming adults: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable. Where appropriate, channels may be designed to capture large wood, contributing to habitat complexity.	May affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Effects of underwater noise on lampreys are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Transforming adults; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	Effects of underwater noise on lampreys are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of transforming adults and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults	Eggs and amocoetes, transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when transforming adults are present.	May cause direct mortality or injury at transforming adult life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and amocoetes life-history stages; may affect transforming adult growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential decreased egg incubation success and amocoetes survival due to turbidity exposure and substrate disturbance. Transforming adults: Stress and behavioral modifications by rearing transforming adults exposed to sediment pulses, migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at transforming adult life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	n/a	n/a	n/a	Lamprey are not dependent on invertebrates for prey. Therefore this stressor will have no effect.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Potential decreased egg incubation success and amocoetes survival due to water loss and stranding. Transforming adults: Barrier to migration, loss of habitat accessibility, stranding, migration delay, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at transforming adult life-history stage, mortality at all life-history stages, and adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Direct injury or mortality from dredging entrainment. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect transforming adult growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Decreased survival due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.

Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect transforming adult survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of Eggs and amocoetes. Transforming adults and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating Eggs and amocoetes. May affect transforming adult growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of transforming adults and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and amocoetes; Transforming adults; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Decreased survival due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and amocoetes; Transforming adults; Adults	Eggs/amocoetes: Decreased incubation success due to smothering of eggs by fine sediments as described for related stressor responses under Water Quality Modifications. Transforming adults: Decreased refuge habitat availability leading to increased stress and predation exposure. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modifications.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Amocoetes	Amocoetes: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect ammocoete survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Amocoetes; Adults	Amocoetes: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Transforming adults and adults: Decreased survival and spawning fitness due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect ammocoete growth and fitness. May affect transforming adult growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and amocoetes; Adults	Eggs and amocoetes: Decreased incubation and rearing success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of Eggs and amocoetes, as well as adult spawning productivity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Amocoetes	Amocoetes: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect ammocoete growth and fitness.
	Altered habitat complexity	Reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults and adults: Decreased migratory refuge habitat availability leading to increased stress and predation exposure resulting in decreased survival, growth and fitness, and adult spawning productivity.		May affect transforming adult and adult survival, growth, and fitness. May affect adult spawning productivity.
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	Eggs and amocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and amocoetes survival. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat suitability during migration, increasing predation exposure and stress. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, amocoetes, and transforming adult life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and transforming adult rearing)	Permanent	Continuous				

Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream or downstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Transforming adults; Adults	Structures designed to promote fish passage will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly implemented may create unintentional passage barriers. Should this occur, the following effects may be realized. Transforming adults: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Transforming adults may be denied the ability to migrate downstream in certain circumstances. Transforming adults may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require competent engineering of all fish passage projects. Evaluate passage requirements of all HCP species occurring or potentially occurring in the affected stream system. Review structure designs for their ability to pass desired fish species at all life-history stages using sound hydraulic engineering and geomorphic design principles.	May affect survival, growth, and fitness at transforming adult life-history stages. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and amocoetes; Transforming adults; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of amocoetes and transforming adults. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Transforming adults; Adults	Adults and transforming adults: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable resting and spawning sites due to effects on habitat complexity may affect survival and spawning productivity.	Design structures for transparency to transport of wood, sediment and organic debris to the greatest extent practicable	May affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Adults	Adults: Mortality, injury, or stress from capture, handling, and relocation. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Transforming adults; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	See recommendations under accidental releases of toxic substances under Structures.	May cause direct injury or mortality; may affect survival, growth, and fitness of transforming adults and survival and spawning productivity of adults.
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Transforming adults; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at transforming adult life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.

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Table A-13 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Pacific Lamprey, River Lamprey, and Brook Lamprey.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Transforming adults; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-14. HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for culverts that could affect fish passage. Therefore no stressor exposure will occur
	Dewatering and fish handling	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Construction/maintenance dredging	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Water Quality Modifications								
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for culverts that could affect fish passage. Therefore no stressor exposure will occur
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for culverts that could affect fish passage. Therefore no stressor exposure will occur
	Altered stream bank and shoreline stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered allochthonous inputs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater–surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for culverts that could affect fish passage. Therefore no stressor exposure will occur
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for culverts that could affect fish passage. Therefore no stressor exposure will occur
	Altered flow regime	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered substrate composition and stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater-surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for culverts that could affect fish passage. Therefore they will not be exposed to stressors resulting from these submechanisms and no effects will result.
	Modified upstream transport of allochthonous nutrients	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Larvae;	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Design projects to effectively pass woody debris and organic material.	May affect juvenile survival, growth, and fitness.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses, increased stress. Behavioral avoidance of affected habitats while disturbance is ongoing.	Limit disturbance causing activities to in-water work windows when affected species is least likely to be present.	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. Adults: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Little is known about the effects of anthropogenic sounds on sturgeon. However, adults are not expected to be sensitive to decreased predator awareness. Regardless, the use of BMPs to manage ambient noise level effects may be appropriate.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Require a TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.
	Flow bypass, fish handling, and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Larvae: Alteration of dispersal mechanisms affecting transport to suitable habitats for rearing. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Conduct all activities within system specific in-water work windows. Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: Alteration of dispersal mechanisms affecting transport to suitable habitats. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Conduct all activities within system specific in-water work windows. Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness. Adults: Short-term displacement to habitats with more abundant forage.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modifications								
		Altered thermal regime	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Larvae;	Fishway construction is expected to have a limited effect on riparian vegetation in most circumstances (relative to the effects of the structure being bypassed). However, larval dispersal and juvenile rearing habitat may be affected in certain circumstances. Larvae: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During construction and maintenance	Short-term	Interannual-decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	The degree to which fish ladders and fishways are expected to affect riparian vegetation conditions is anticipated to be insignificant relative to the effects of the flow control structure they are associated with. Therefore, the magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant in most circumstances. However, in cases where fish ladders are installed to bypass natural barriers, more extensive riparian effects are possible. The effects of this worst-case scenario are similar to those described for roughened channels. This scenario is not expected to affect sturgeon, which reside in mainstem river environments.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects are expected to be insignificant and discountable in most cases.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects are expected to be insignificant and discountable in most cases.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults;		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects are expected to be insignificant and discountable in most cases.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	Effects are expected to be insignificant and discountable in most cases.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults		Avoid disturbance of vegetation along stream.	Effects are expected to be insignificant and discountable in most cases.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which fish ladders/fishways affect aquatic vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	Complete or partial barriers to upstream fish passage imposing the following stressors: ▪ Inability to access otherwise suitable rearing or spawning habitats. ▪ Energy exertion or injury during attempts to navigate barrier structure ▪ Run-timing, size, or life-history specific barrier conditions that impose a selection pressure on the affected population	Seasonal to year-round (depending on the nature of the barrier condition)	Permanent (may increase in severity over time if barrier condition is created by geomorphic changes)	Continuous	Juveniles; Adults	Fish ladders and fishways will generally improve the condition of this submechanism. However, designs that are poorly conceived or improperly maintained may create unintentional passage barriers. Should this occur, the following effects may be realized Juveniles: Loss of access to favorable upstream or downstream rearing habitats will increase competition for remaining suitable areas, and force individuals to occupy marginal habitats. Juveniles may also exert excess energy and incur injury attempting to navigate impassable structures. These stressors may lead to decreased survival, growth, and fitness. Adults: Loss of access to suitable spawning habitats will result in decreased spawning productivity. Attempts to navigate impassible structures may lead to excess exertion and possible injury. These combined stressors may lead to decreased survival and decreased spawning fitness and productivity. All exposed life-history stages: Partial barriers to fish passage may impose selection pressures that affect the diversity of the affected population. This in turn may affect the evolutionary fitness of the stock, with broad implications for population productivity and diversity.	Require assessment of the hydraulic effects of the project before permitting and require consideration of the full range of fish passage needs in design. Incorporate monitoring and maintenance requirements into the HPA.	May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity. May affect population productivity and diversity.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness of larvae and juveniles. May affect adult spawning fitness and productivity through long-term effects on habitat complexity.

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no stressor exposure will occur as a result of these submechanisms.
	Flow bypass, fish handling, and channel rewatering	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Construction/maintenance dredging	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Water Quality Modifications								
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no water quality related stressor exposure will occur.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no stressor exposure will occur as a result of these submechanisms.
	Altered stream bank and shoreline stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered allochthonous inputs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater–surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no stressor exposure will occur as a result of these submechanisms.
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a		
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no stressor exposure will occur as a result of these submechanisms.
	Altered flow regime	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered substrate composition	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater-surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no stressor exposure will occur as a result of these submechanisms.
	Modified upstream transport of allochthonous nutrients	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Modified downstream transport of wood, sediment and organic material	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for fish passage weirs. Therefore no stressor exposure will occur as a result of these submechanisms.
	Flow bypass, fish handling, and channel rewatering	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Construction/maintenance dredging	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modifications								
	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for roughened channel projects intended to improve fish passage. Therefore no water quality related stressor exposure will occur.
	Riparian Vegetation Modifications								
	Altered shading, solar input and ambient air temperature	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for fish passage weirs. Therefore no stressor exposure will occur as a result of these submechanisms.
	Altered stream bank and shoreline stability	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered allochthonous inputs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater–surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Aquatic Vegetation Modifications								
	Altered autochthonous production	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for fish passage weirs. Therefore no stressor exposure will occur as a result of these submechanisms.
	Altered habitat complexity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for fish passage weirs. Therefore no stressor exposure will occur as a result of these submechanisms.
	Altered flow regime	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered substrate composition	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Altered groundwater-surface water exchange	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	White and green sturgeon do not occur in riverine environments in Washington State suitable for fish passage weirs. Therefore no stressor exposure will occur as a result of these submechanisms.
	Modified upstream transport of allochthonous nutrients	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Modified downstream transport of wood, sediment and organic material	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Established capture and handling protocols to avoid and minimize adverse impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Eggs and larvae; Juveniles; Adults	Water quality effects are similar to those described for accidental releases of toxic substances under Fish Ladders/Water Quality Modification.	Require an operational TESC plan.	May cause direct injury or mortality; may affect survival growth and fitness at all life-history stages.

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Table A-14 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Green Sturgeon and White Sturgeon.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	Seasonal (associated with operations)	Permanent	Variable (depending on operational limitations).	Juveniles; Adults	All exposed life-history stages: Trap and haul programs may result in disruption or alteration of the migratory corridor when fish are not released in the immediate vicinity of the barrier being bypassed. This may in turn cause fish to select spawning or rearing habitats that are less suitable than the natural habitat, or increase stress and exertion by imposing increased travel distance. These stressors may affect survival, growth, and fitness. Alteration of the migratory corridor may also impose unintended selection pressures on the affected population, with adverse effects on phenotypic diversity. Trap and haul programs may impose additional selection pressures on the population if the full range of size and run-timing diversity is not captured.	Operate trap and haul programs to mimic volitional passage around barriers to the greatest extent possible (i.e., release fish immediately upstream and downstream of barriers where practicable and consistent with migratory behavior).	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival, fitness, and spawning productivity. May affect population diversity and spatial structure.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	Seasonal to year-round (depending on nature of barrier condition)	Permanent	Variable (depending on nature of barrier condition).	Juveniles; Adults	All exposed life-history stages: Trap and haul operations can impose multiple unintentional barrier conditions when operations do not capture the full range of run timing and fish size diversity. This may in turn impose selection pressures on the affected population, reducing phenotypic diversity.	Evaluate the operational plan and require monitoring where necessary to ensure that the full range of life-history diversity is expressed.	May affect population diversity and spatial structure.

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-24. HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of exposure to this stressor are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses (withdrawal into shell), delayed feeding. Behavioral avoidance of affected habitats while disturbance is ongoing.	No specific recommendations	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juvenile capture and relocation is impractical, likely leading to mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Risk of entrainment for these species is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	The effects of exposure to this stressor are unknown.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect adult and juvenile growth and fitness.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Stress and behavioral modifications when exposed to sediment pulses, reduced foraging effectiveness.	Adhere to system-specific in-water work windows. Avoid work during sensitive spawning periods.	May affect juvenile and adult growth and fitness at juvenile life-history stage.

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	n/a	n/a	n/a	These species are non-migratory and insensitive to temporary barriers to passage.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	All life-history stages: Direct injury or mortality from dredge entrainment. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses during construction where practicable.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Spire snails belong to the Hydrobiidae, a family of snails having gills. The gill tissue is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, the extent of riparian modification resulting from structure removal/replacement/retrofitting for fish passage purposes is expected to be limited in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Adults			

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult spire snail and CR limpet. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth and fitness.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect survival, growth, and fitness.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of exposure to this stressor are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses (withdrawal into shell), delayed feeding. Behavioral avoidance of affected habitats while disturbance is ongoing.	No specific recommendations	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juvenile capture and relocation is impractical, likely leading to mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Risk of entrainment for these species is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	The effects of exposure to this stressor are unknown.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect adult and juvenile growth and fitness.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles and adults</u>: Stress and behavioral modifications when exposed to sediment pulses, reduced foraging effectiveness.	Adhere to system-specific in-water work windows. Avoid work during sensitive spawning periods.	May affect juvenile and adult growth and fitness at juvenile life-history stage.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	n/a	n/a	n/a	These species are non-migratory and insensitive to temporary barriers to passage.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	<u>All life-history stages</u>: Direct injury or mortality from dredge entrainment. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Spire snails belong to the Hydrobiidae, a family of snails having gills. The gill tissue is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, the extent of riparian modification resulting from structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	These effects are expected to be insignificant.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	These effects are expected to be insignificant.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	These effects are expected to be insignificant.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles; Adults		Avoid disturbance of vegetation along stream.	These effects are expected to be insignificant.
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult spire snail and CR limpet. However, the extent of aquatic vegetation modification caused by structure removal/ replacement/ retrofitting for fish passage purposes is expected to be limited in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	These effects are expected to be insignificant.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of exposure to this stressor are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses (withdrawal into shell), delayed feeding. Behavioral avoidance of affected habitats while disturbance is ongoing.	No specific recommendations	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juvenile capture and relocation is impractical, likely leading to mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Risk of entrainment for these species is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	The effects of exposure to this stressor are unknown.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect adult and juvenile growth and fitness.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Stress and behavioral modifications when exposed to sediment pulses, reduced foraging effectiveness.	Adhere to system-specific in-water work windows. Avoid work during sensitive spawning periods.	May affect juvenile and adult growth and fitness at juvenile life-history stage.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	n/a	n/a	n/a	These species are non-migratory and insensitive to temporary barriers to passage.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	All life-history stages: Direct injury or mortality from dredge entrainment. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Spire snails belong to the Hydrobiidae, a family of snails having gills. The gill tissue is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Roughened channel creation may involve extensive modification of existing riparian vegetation, with attendant effects on HCP species occurring in the affected environment. Spire snails and Columbia River limpet are sensitive to turbidity and water quality impacts imposed by riparian effects. Juveniles and adults: See effects for related stressors under water quality modification. Effects on habitat complexity and food web productivity may affect survival, growth, and fitness of juveniles and adults.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Adults			

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult spire snail and CR limpet. Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to decreased growth and fitness.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth, and fitness, as well as adult spawning productivity.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Juvenile and adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, fitness and spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect survival, growth, and fitness.
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of exposure to this stressor are unknown.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Juveniles; Adults	All exposed life-history stages: Startle responses (withdrawal into shell), delayed feeding. Behavioral avoidance of affected habitats while disturbance is ongoing.	No specific recommendations	May affect behavior.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	The effects of underwater noise on spire snail and giant Columbia River limpet are a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modifications.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	See effects for related stressors under Water Quality Modifications.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juvenile capture and relocation is impractical, likely leading to mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Risk of entrainment for these species is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	The effects of exposure to this stressor are unknown.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect juvenile and adult growth and fitness.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Stress and behavioral modifications when exposed to sediment pulses, reduced foraging effectiveness.	Adhere to system-specific in-water work windows. Avoid work during sensitive spawning periods.	May affect juvenile and adult growth and fitness.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect juvenile and adult growth and fitness.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	n/a	n/a	n/a	These species are non-migratory and insensitive to temporary barriers to passage.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Localized decrease in periphyton coverage	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	All life-history stages: Direct injury or mortality from dredge entrainment. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Spire snails belong to the Hydrobiidae, a family of snails having gills. The gill tissue is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, riparian modification resulting from fish passage weirs is expected to be limited in extent. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Adults			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult spire snail and CR limpet. However, the extent of aquatic vegetation modification caused by fish passage weirs is expected to be limited. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	<u>Design</u>: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect survival, growth, and fitness.
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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Table A-24 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Columbia River Spire Snail and Giant Columbia River Limpet.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Spire snail and Columbia River limpet are not expected to be the subject of trap and haul operations, however some potential for exposure to infrequent short-term water quality effects could occur. Should exposure occur, these stressors may impose short-term effects on survival, growth, and fitness. <u>All exposed life history stages (mountain sucker only)</u>: Water quality effects are similar to those described for accidental releases of toxic substances under Structures.	Require an operational TESC plan.	See effects for related stressors under Water Quality Modification
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Passage barriers	Unintentional passage barriers imposed by operational limitations	n/a	n/a	n/a	n/a	n/a	n/a	

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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Table A-25. HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Culverts (removed/replaced/retrofitted for fish passage)									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All life-history stages: The effect of construction noise on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of visual and physical disturbance on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	The effects of exposure to this stressor are unknown.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	All life-history stages: The effect of altered ambient noise levels on California floater and western ridged mussels is a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: Capture and removal of larvae impractical, high likelihood of larval mortality. Adults and juveniles: Adults appear insensitive to handling stress, however inadvertent dispersal when relocated can affect population productivity. Juvenile sensitivity to handling stress unknown. These species are also sensitive to effects on host fish.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Adhere to in-water work windows	May cause larval mortality. May affect adult population productivity. Effects on host fish may also affect population productivity.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: High likelihood of mortality from pump entrainment or impingement on screen filters. Juveniles and adults: Risk of entrainment for juveniles and adults is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	High likelihood of larval mortality from entrainment or impingement. The effects of juvenile and adult exposure to this stressor are expected to be low. Effects on host fish will indirectly affect population productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Potential decreased incubation success and survival due to water loss and stranding. Juvenile and adults: Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival in all life stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Glochida; Juveniles; Adults	Glochidia: Direct injury or mortality from dredge entrainment. Juveniles and adults: Effects of stressor exposure vary from mortality due to mechanical injury, burial and starvation, to behavioral alteration depending on nature of dredging activity. Inadvertent dispersal may affect population productivity. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications. Effects on host fish may also lead to indirect effects on population productivity.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. Juveniles and adults: A physiological response to exposure at toxic levels, causing mortality or injury leading to reduced fitness is a data gap.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism specific measures as appropriate.	May affect survival of larvae. May affect juvenile survival and adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Gill tissue in these species is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, riparian modification resulting from fish passage related structure retrofits is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Adults			

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult freshwater mussels. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth and fitness.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	Effects on host species that affect abundance and distribution may in turn affect abundance and distribution of freshwater mussel species.	Follow recommendations for maintaining fish passage.	May affect abundance and distribution.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthonous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect survival, growth, and fitness.
Fish Ladders/Fishways									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All life-history stages: The effect of construction noise on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of visual and physical disturbance on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	The effects of exposure to this stressor are unknown.

Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	All life-history stages: The effect of altered ambient noise levels on California floater and western ridged mussels is a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: Capture and removal of larvae impractical, high likelihood of larval mortality. Adults and juveniles: Adults appear insensitive to handling stress, however inadvertent dispersal when relocated can affect population productivity. Juvenile sensitivity to handling stress unknown. These species are also sensitive to effects on host fish.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Adhere to in-water work windows	May cause larval mortality. May affect adult population productivity. Effects on host fish may also affect population productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: High likelihood of mortality from pump entrainment or impingement on screen filters. Juveniles and adults: Risk of entrainment for juveniles and adults is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	High likelihood of larval mortality from entrainment or impingement. The effects of juvenile and adult exposure to this stressor are expected to be low. Effects on host fish will indirectly affect population productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Potential decreased incubation success and survival due to water loss and stranding. Juvenile and adults: Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival in all life stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Glochida; Juveniles; Adults	Glochidia: Direct injury or mortality from dredge entrainment. Juveniles and adults: Effects of stressor exposure vary from mortality due to mechanical injury, burial and starvation, to behavioral alteration depending on nature of dredging activity. Inadvertent dispersal may affect population productivity. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications. Effects on host fish may also lead to indirect effects on population productivity.
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Gill tissue in these species is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.

Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, riparian modification resulting from fish passage related structure retrofits is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	These effects are expected to be insignificant.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	These effects are expected to be insignificant.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	These effects are expected to be insignificant.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles; Adults		Avoid disturbance of vegetation along stream.	These effects are expected to be insignificant.

**Table A-25 (continued).	HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.**

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult freshwater mussels. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	These effects are expected to be insignificant.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	Effects on host species that affect abundance and distribution may in turn affect abundance and distribution of freshwater mussel species.	Follow recommendations for maintaining fish passage.	May affect abundance and distribution.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
Roughened Channels									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All life-history stages: The effect of construction noise on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of visual and physical disturbance on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	The effects of exposure to this stressor are unknown.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	All life-history stages: The effect of altered ambient noise levels on California floater and western ridged mussels is a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: Capture and removal of larvae impractical, high likelihood of larval mortality. Adults and juveniles: Adults appear insensitive to handling stress, however inadvertent dispersal when relocated can affect population productivity. Juvenile sensitivity to handling stress unknown. These species are also sensitive to effects on host fish.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Adhere to in-water work windows	May cause larval mortality. May affect adult population productivity. Effects on host fish may also affect population productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: High likelihood of mortality from pump entrainment or impingement on screen filters. Juveniles and adults: Risk of entrainment for juveniles and adults is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	High likelihood of larval mortality from entrainment or impingement. The effects of juvenile and adult exposure to this stressor are expected to be low. Effects on host fish will indirectly affect population productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Potential decreased incubation success and survival due to water loss and stranding. Juvenile and adults: Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival in all life stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Glochida; Juveniles; Adults	Glochidia: Direct injury or mortality from dredge entrainment. Juveniles and adults: Effects of stressor exposure vary from mortality due to mechanical injury, burial and starvation, to behavioral alteration depending on nature of dredging activity. Inadvertent dispersal may affect population productivity. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications. Effects on host fish may also lead to indirect effects on population productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Gill tissue in these species is sensitive to injury or clogging by elevated suspended sediment levels. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, riparian modification resulting from fish passage related structure retrofits is expected to be limited in extent in comparison to initial structure installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Adults			

Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juvenile and adult freshwater mussels. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	Effects on host species that affect abundance and distribution may in turn affect abundance and distribution of freshwater mussel species.	Follow recommendations for maintaining fish passage.	May affect abundance and distribution.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect survival, growth, and fitness.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Weirs									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All life-history stages: The effect of construction noise on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Visual and physical disturbance	During project construction and maintenance activities	Temporary	Interannual to decadal (during construction and maintenance)	Glochidia larvae; Juveniles; Adults	All life-history stages: The effect of visual and physical disturbance on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	The effects of exposure to this stressor are unknown.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	All life-history stages: The effect of altered ambient noise levels on California floater and western ridged mussels is a data gap.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	The effects of exposure to this stressor are unknown.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Dewatering and fish handling	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: Capture and removal of larvae impractical, high likelihood of larval mortality. Adults and juveniles: Adults appear insensitive to handling stress, however inadvertent dispersal when relocated can affect population productivity. Juvenile sensitivity to handling stress unknown. These species are also sensitive to effects on host fish.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Adhere to in-water work windows	May cause larval mortality. May affect adult population productivity. Effects on host fish may also affect population productivity.

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Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia; Juveniles; Adults	Glochidia: High likelihood of mortality from pump entrainment or impingement on screen filters. Juveniles and adults: Risk of entrainment for juveniles and adults is currently unknown, but is anticipated to be low.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	High likelihood of larval mortality from entrainment or impingement. The effects of juvenile and adult exposure to this stressor are expected to be low. Effects on host fish will indirectly affect population productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Stream bed disturbance (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access (during construction and maintenance or dam removal)	n/a	n/a	n/a	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Potential decreased incubation success and survival due to water loss and stranding. Juvenile and adults: Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival in all life stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modifications.
		Entrainment of benthic organisms, increased suspended solids	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Glochida; Juveniles; Adults	Glochidia: Direct injury or mortality from dredge entrainment. Juveniles and adults: Effects of stressor exposure vary from mortality due to mechanical injury, burial and starvation, to behavioral alteration depending on nature of dredging activity. Inadvertent dispersal may affect population productivity. See responses described for related stressors under Water Quality Modifications.	Avoid turbidity effects above background levels.	May cause direct injury or mortality. See effects for related stressors on all life-history stages under Water Quality Modifications. Effects on host fish may also lead to indirect effects on population productivity.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modifications								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Adults and juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes).	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect adult and juvenile survival, growth and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modifications								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Stressors related to extensive modification of riparian vegetation can impose a number of effects on these species. However, riparian modification resulting from fish passage related removal/ replacement/ retrofit of the structure is expected to be limited in extent in comparison to initial installation. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor across all submechanisms.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect behavior and distribution. May affect survival, growth, and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Adults			
	Aquatic Vegetation Modifications								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of freshwater mussels. However, the extent of aquatic vegetation modification caused by removing/ replacing/ retrofitting structures for fish passage purposes is expected to be limited in extent in comparison to initial structure installation and these effects will recover relatively rapidly. Therefore, the additional incremental effects on HCP species from this impact mechanism are expected to be similarly minor.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness for intermediate-term period.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic & Geomorphic Modifications								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	Eggs and larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of eggs) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Barriers to fish passage	n/a	n/a	n/a	n/a	n/a	Effects on host species that affect abundance and distribution may in turn affect abundance and distribution of freshwater mussel species.	Follow recommendations for maintaining fish passage.	May affect abundance and distribution.
	Modified upstream transport of allochthonous nutrients	Decreased food web productivity induced by reduced upstream transport of allochthonous nutrients (e.g., marine derived nutrients) in fish carcasses	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Reduced supply of allochthononous nutrients can have a profound effect on food web productivity, with long-term implications. Reduced abundance and availability of primary prey items is the most immediate effect, resulting in decreased survival, growth, and fitness. Over the long-term, riparian function can become diminished as nutrients are exported from the system and not replaced from allochthonous sources. This can lead to related effects on habitat complexity, influencing the availability of resting and spawning habitat, affecting adult spawning fitness and productivity.	Follow recommendations for avoiding effects on fish passage.	May affect survival, growth, and fitness.
	Modified downstream transport of wood, sediment and organic material	Decreased habitat complexity and food web productivity	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Decreased availability of suitable rearing habitats and undesirable effects on food web productivity may lead to decreased survival, growth, and fitness	Design structures for transparency to transport of wood, sediment, and organic debris to the greatest extent practicable.	May affect survival, growth, and fitness.

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Table A-25 (continued). HPA HCP Fish Passage Structures Exposure and Response Matrix for Western Ridged Mussel and California Floater Mussel.

Sub-activity Type	Impact Mechanism/ Submechanism	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Trap and Haul Operations									
	Operational Activities								
	Fish capture, handling, and release	Fish removal, relocation, and exclusion	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Accidental introduction of toxic substances	Exposure to fuel, lubricants, fish anesthetics or other toxicants from accidental operational spills	During capture, transport, and release operations	Short-term	Annual	Juveniles; Adults	Freshwater mussels are not expected to be the subject of trap and haul operations, however some potential for exposure to infrequent short-term water quality effects could occur. Should exposure occur, these stressors may impose short-term effects on survival, growth, and fitness.	Require an operational TESC plan.	See effects for related stressors under Water Quality Modification
	Ecosystem Fragmentation								
	Alteration of migratory corridor	Alterations of migratory pathway caused by release location	n/a	n/a	n/a	n/a	Effects on host species that affect abundance and distribution may in turn affect abundance and distribution of freshwater mussel species.	Follow recommendations for maintaining fish passage.	May affect abundance and distribution.
	Passage barriers	Unintentional passage barriers imposed by operational limitations	n/a	n/a	n/a	n/a			

n/a = Not applicable, no exposure to the submechanism and related stressors will occur and there are therefore no effects.

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