2001 Evaluation of Juvenile Fall Chinook Salmon Stranding on the Hanford Reach of the Columbia River

Prepared for
The Bonneville Power Administration
The Public Utility District Number 2 of Grant County

John Nugent
Todd Newsome
Paul Hoffarth
Michael Nugent
Wendy Brock
Michael Kuklinski, Jr.

Washington Department of Fish and Wildlife

May 29, 2002

BPA Contract Number 9701400
GCPUD Contracts Document 97BI30417

Executive Summary

The Washington Department of Fish and Wildlife (WDFW) in cooperation with the Bonneville Power Administration (BPA), Grant County Public Utility District (GCPUD), and Pacific Northwest National Laboratory (PNNL), performed the *2001 Evaluation of Juvenile Fall Chinook Salmon Stranding on the Hanford Reach of the Columbia River*. The 2001 evaluation was the fifth year of a multi-year study to assess the impacts of water fluctuations from Priest Rapids Dam on rearing juvenile fall chinook salmon. The field effort was performed from March 14 through June 28.

The objectives of the 2001 evaluation were to collect basic information on the physical parameters of the Hanford Reach, evaluate the extent of stranding and entrapment of juvenile fall chinook salmon and other fish species, and identify critical habitat zones. PNNL will use this information to develop a model for determining susceptibility of juvenile fall chinook salmon to stranding and entrapment due to flow fluctuations. The overall goal will be to develop a long term agreement for the protection of juvenile fall chinook during emergence and rearing.

River and meteorological conditions on the Hanford Reach during the 2001 juvenile fall chinook salmon emergence and rearing period (March–July) were marked by below average river flows, above normal river temperatures, near normal ambient air temperatures, and below average solar radiation levels. Priest Rapids Project discharges averaged 70.9 kcfs from March 21 through June 10 (range 37.5 kcfs to 152.2 kcfs). Mean daily fluctuation in discharges from Priest Rapids Dam during the Protection Program (March 26 – June 10) was 23.2 kcfs (range 0.7 kcfs to 84.5 kcfs).

Emergence of juvenile fall chinook salmon in 2001, as calculated under the terms of the 1988 Vernita Bar Settlement Agreement (GCPUD 1988), was estimated to start on April 1. Population index surveys were subsequently initiated on March 21 to account for possible early emergence. Implementation of the 2001 Interim Protection Program began March 26. The Protection Program ended on June 10 and evaluation field activities were continued through June 28.

A total of 434 random plots encompassing 86,526 m^2 (931,388 ft^2) were sampled in 2001 between April 13 and June 28, 2001. Flows were relatively stable through May 21 with limited fluctuations greater than 10 kcfs. Though few in number, fluctuations occurring during this early period of emergence and rearing often resulted in large numbers of stranded/entrapped juvenile fall chinook salmon. From May 6 through May 10, increased numbers of juvenile fall chinook salmon were found in random plots as flows gradually decreased from 72.8 kcfs to 52.6 though no significant fluctuations occurred during this period. By May 28, juvenile fall chinook salmon found in random samples had decreased though daily flow fluctuations had risen in accordance with the criteria in the protection plan indicating reduced susceptibility.

Random plots contained 3,313 juvenile fall chinook salmon in 2001. Field crews recorded 3,238 direct mortalities consisting of the 316 stranded and 2,922 thermal induced fatalities. Fish were first encountered in random plots on April 13 and last found on June 22. The majority of juvenile fall chinook salmon mortalities were sampled during the month of April (2,278). The estimated total number of juvenile fall chinook salmon stranding and entrapment mortalities in the study area in 2001 was calculated to be 1,628,878 with a 95% confidence interval between –286,153 and 3,543,910. Juvenile fall chinook salmon placed at risk of mortality due to stranding and entrapment was calculated to be 1,663,636 with a 95% confidence interval between –252,186 and 3,579,458. Juvenile fall chinook salmon were found throughout the SHOALS defined study area at a variety flow bands but the highest concentrations were found at the island complex areas of Locke Island (600-610 Rkm) at flows of 40-80 kcfs.

An estimated 27,979,577 fall chinook fry emerged in the Hanford Reach in 2001. Sampling to assess juvenile fall chinook salmon abundance and fish size began on March 14, two weeks prior to the estimated start of emergence on April 1 and ended on June 27. A total of 37,036 juvenile fall chinook salmon were seined during this period. Peak abundance was observed from April 18 to May 23.

Juvenile fall chinook salmon with fork lengths at or below 42 mm made up a minimum of 25% of the fish seined in the Hanford Reach through May 23 and fish of this size remained in the samples until June 27. Juvenile fall chinook salmon with fork lengths greater than 59 mm, the size threshold that individuals are thought to become less susceptible to entrapment (Nugent et al. 2001), began to appear in the samples on April 11 but were not collected in considerable numbers (>5%) until June 13.

The Emergency Management Team monitored entrapments in primary fall chinook salmon rearing areas from March 26 to June 28. A total of 27,639 juvenile fall chinook salmon were seined from 63 entrapments. Juvenile fall chinook salmon were observed in an additional ten entrapments that were too large too seine. A total of 98 entrapments were monitored in 2001. Field crews recorded 7,927 direct mortalities at the time entrapments were sampled. In addition to juvenile fall chinook salmon, thousands of resident fish were reported entrapped.

Juvenile fall chinook were susceptible to stranding/entrapment from March 14, date first found fish in index samples, through the end of index sampling on June 27, minimum chinook fork lengths less than 60mm. Based on chinook "at risk" in random samples and population abundance from index sampling, the primary period when operations at Priest Rapids Dam were most likely to have significant impacts to the juvenile fall chinook population was from April 11 through May 30. Data from 1999, 2000, and 2001 all indicate decrease susceptibility beginning at roughly 200 temperature units Celsius after the estimated end of emergence, May 27 in 2001. This trend was observed in chinook "at risk" and in the length frequency data for all three years. In 2001, the number of juvenile fall chinook salmon at risk decrease dramatically after May 28 though daily fluctuations in discharge from Priest Rapids were relatively high.

The joint fish managers, consisting of WDFW, the Columbia River Intertribal Fish Commission, the Tribes of the Columbia River Basin, the Oregon Department of Fish and Wildlife, NMFS, and USFWS, and the power managers, consisting GCPUD, BPA, the United States Bureau of Reclamation, and the Mid-Columbia Public Utility Districts (Chelan and Douglas Counties), should continue to work together through the Hanford Policy Group meetings to refine annual interim protection plans to protect emergent and rearing juvenile fall chinook salmon in the Hanford Reach area of the Columbia River until a permanent agreement can be adopted. A permanent agreement will need to allow adaptive management options for fish management and hydropower as conditions change.

Table of Contents

List of Figures

List of Tables

Introduction

The Washington Department of Fish and Wildlife (WDFW) has been contracted through the Bonneville Power Administration (BPA) and the Grant County Public Utility District (GCPUD) to perform an evaluation of juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) stranding on the Hanford Reach of the Columbia River. The evaluation, in the fifth year of a multi-year study, has been developed to assess the impacts of water fluctuations from Priest Rapids Dam on rearing juvenile fall chinook salmon, other fishes, and benthic macroinvertebrates of the Hanford Reach. This document provides the results of the 2001 field season.

Background

Impetus for the Evaluation

The BPA has been directed by the National Marine Fisheries Service (NMFS) under the Endangered Species Act - Section 7 - Biological Opinion on the Reinitiating of Consultation on 1994-1998 Operation of The Federal Columbia River Power System and Juvenile Transportation Program to perform the following:

> "Beginning in 1995, BPA will evaluate the affect of power peaking operations on juvenile and adult salmon passage and on the river ecology downstream of Bonneville Dam and on the Hanford Reach, downstream of Priest Rapids Dam. Contingent on the results of these evaluations BPA will develop a plan to decrease power peaking operations from mid-March through mid-December on the lower Snake and Columbia Rivers (page 162, #11)".

In addition, as an objective of the 1994 Columbia River Basin Fish and Wildlife Program, BPA has been directed to perform the following:

> "Beginning in 1995, evaluate alternative ramping rates for flow fluctuations at mainstem Snake and Columbia River dams to constrain reductions and increases in total flow per 24-hour period at these projects (Page 5-20, 5.1D.4)".

This evaluation of juvenile fall chinook stranding on the Hanford Reach is consistent with both of these objectives.

Description of Stranding and Entrapment Conditions on the Hanford Reach

The Hanford Reach supports the larger of the only two remaining healthy naturally spawning fall chinook salmon populations in the Columbia River System (Huntington et al.1996). This population is a primary source of ocean and freshwater sport, commercial and in-river tribal fisheries (Dauble and Watson 1997) and is a primary component of the Pacific Salmon Treaty between the United States and Canada. River flows for this section of the Columbia River are manipulated by discharge from Priest Rapids Dam. Flow fluctuations from Priest Rapids Dam occur rapidly due to changes in hydroelectric power generation (power peaking), irrigation, water storage, and flood control. These fluctuations have been observed to cause stranding and entrapment of juvenile fall chinook salmon on gently sloped banks, gravel bars and in pothole depressions on the Hanford Reach (Page 1976, Becker et al. 1981, DeVore 1988, Geist 1989, Wagner 1995, Ocker 1996, Wagner et al. 1999, Nugent et al. 2001).

Stranding of juvenile fall chinook salmon occurs when the fish are trapped on or beneath the unwatered substrate as the river level recedes. Entrapment occurs when the fish are separated from the main river channel in depressions as the river level recedes. Entrapped fish may become stranded when depressions drain completely. Fish mortality occurs from stranding, warming of water in entrapments (thermal stress), and by piscivorous and avian predation in small shallow entrapments.

The impact of river fluctuations due to operation of hydroelectric facilities on rearing salmonids has been assessed on numerous Columbia River tributaries and other river systems (Thompson 1970, Witty and Thompson 1974, Phinney 1974a and 1974b, Bauersfeld 1978, Tipping et al. 1978 and 1979, Becker et al. 1981, Woodin 1984, and Beck 1989) but limited research has been conducted on the Hanford Reach (Page 1976, Becker et al. 1981). The 2001 evaluation has been performed to estimate the loss of juvenile fall chinook salmon on the Hanford Reach to stranding and entrapment and for directing the future management of flows from Priest Rapids Dam.

Description of the Hanford Reach

The Hanford Reach stretches from Priest Rapids Dam 82 km downstream to Richland, Washington (**Figure 1**). The physiography, river dynamics, and climate of the area create a unique habitat for wildlife and fish populations.

Physiography

The United States Atomic Energy Commission requisitioned the lands surrounding the Hanford Reach for the siting of facilities to produce plutonium for the first atomic weapons in 1943. The Hanford Site has been owned and maintained by the United States Department of Energy (DOE) with portions of the site being managed by the United States Fish and Wildlife Service (USFWS), and WDFW. Due to the secure nature of the facilities, the Hanford Reach and the surrounding lands have remained protected and only limited development has occurred in small intensely disturbed areas adjacent to the facilities. The security of the site has unintentionally preserved many significant biological resources and cultural, archaeological, geological, and historic sites. The undeveloped areas contain one of the largest remnant sections of shrub-steppe ecosystem in the Columbia River Basin. The uniqueness of the Hanford Reach was recognized on June 9, 2000 when it was proclaimed a national monument by then President William J. Clinton.

For descriptive purposes, the Hanford Reach can be broken down into five distinct river sections. These sections are Priest Rapids Dam (Rkm 639.1) to Coyote Rapids (Rkm 615.6), from Coyote Rapids to the beginning of the White Bluffs (Rkm 605.1), from the beginning of the White Bluffs to Hanford Slough (Rkm 582.6), Hanford Slough to Savage Island (Rkm 572.9), and from Savage Island to the McNary Pool (Rkm 545.6) in Richland. Detailed plan views of the Hanford Reach are provided in **Figures 2, 3, and 4**.

The first segment of river from Priest Rapids Dam to Coyote Rapids flows to the east. This section of river consists of a series of gentle meanders. The meanders are characterized by cutbanks on the outside of the meanders and point bars on the inside downstream portion of the meanders. The cutbanks in this section are typified by steep embankments or to a lesser extent rock walls. The cutbank from Rkm 637.3 to Rkm 632.4 is an outcropping of basalt associated with the terminus of Umtanum Ridge. Gentle embankments, flats and downstream gravel bars distinguish the point bars in this section. Notable downstream gravel bars critical to fall chinook salmon spawning are Vernita Bar (Rkm 632.4) and a gravel bar immediately upstream of Coyote Rapids at Rkm 616.4.

At Coyote Rapids the river turns and flows to the northeast. The next section of river from Coyote Rapids to the beginning of the White Bluffs is straight and channelized with relatively steep embankments. Some fall chinook salmon spawning occurs at the top of the island at Rkm 606.7.

At the beginning of the White Bluffs, the river makes an abrupt turn to the southeast. Unconsolidated bluffs on the northeast bank and island complexes dominate this next section of river from the beginning of the White Bluffs to the bottom of Hanford Slough. The river becomes braided through this segment and the bluffs rise to greater than 150 m above the surface of the river. The island complexes with associated islands, gravel bars and backwater sloughs provide extensive critical spawning and rearing habitat for fall chinook salmon.

Below Hanford Slough the river continues to flow to the southeast to the bottom of Savage Island. This section of the river from the bottom of Hanford Slough to the bottom of Savage Island is straight and channelized with relatively steep embankments. No observed fall chinook salmon spawning occurs in this section of the river.

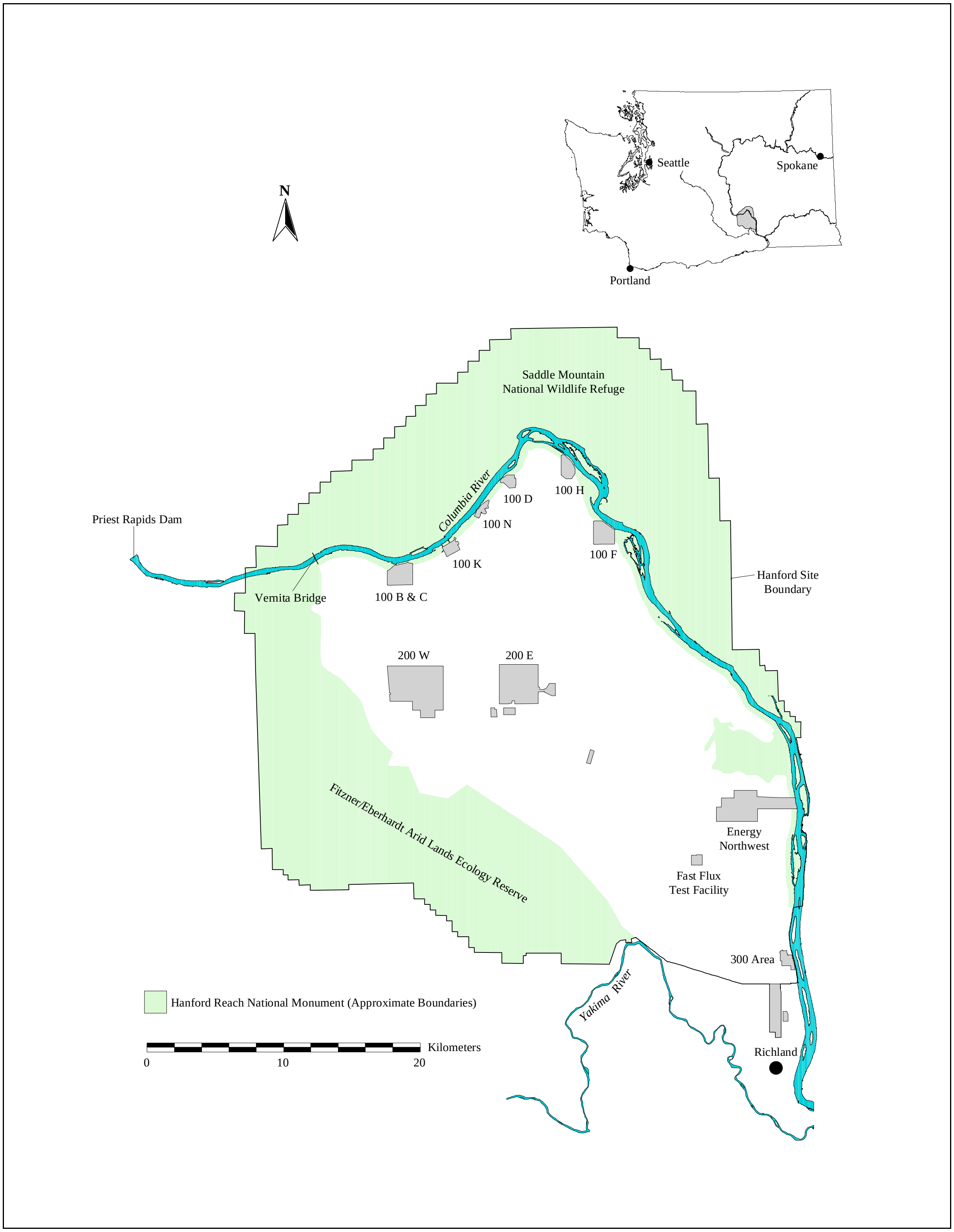

Figure 1. The Hanford Reach of the Columbia River, Washington.

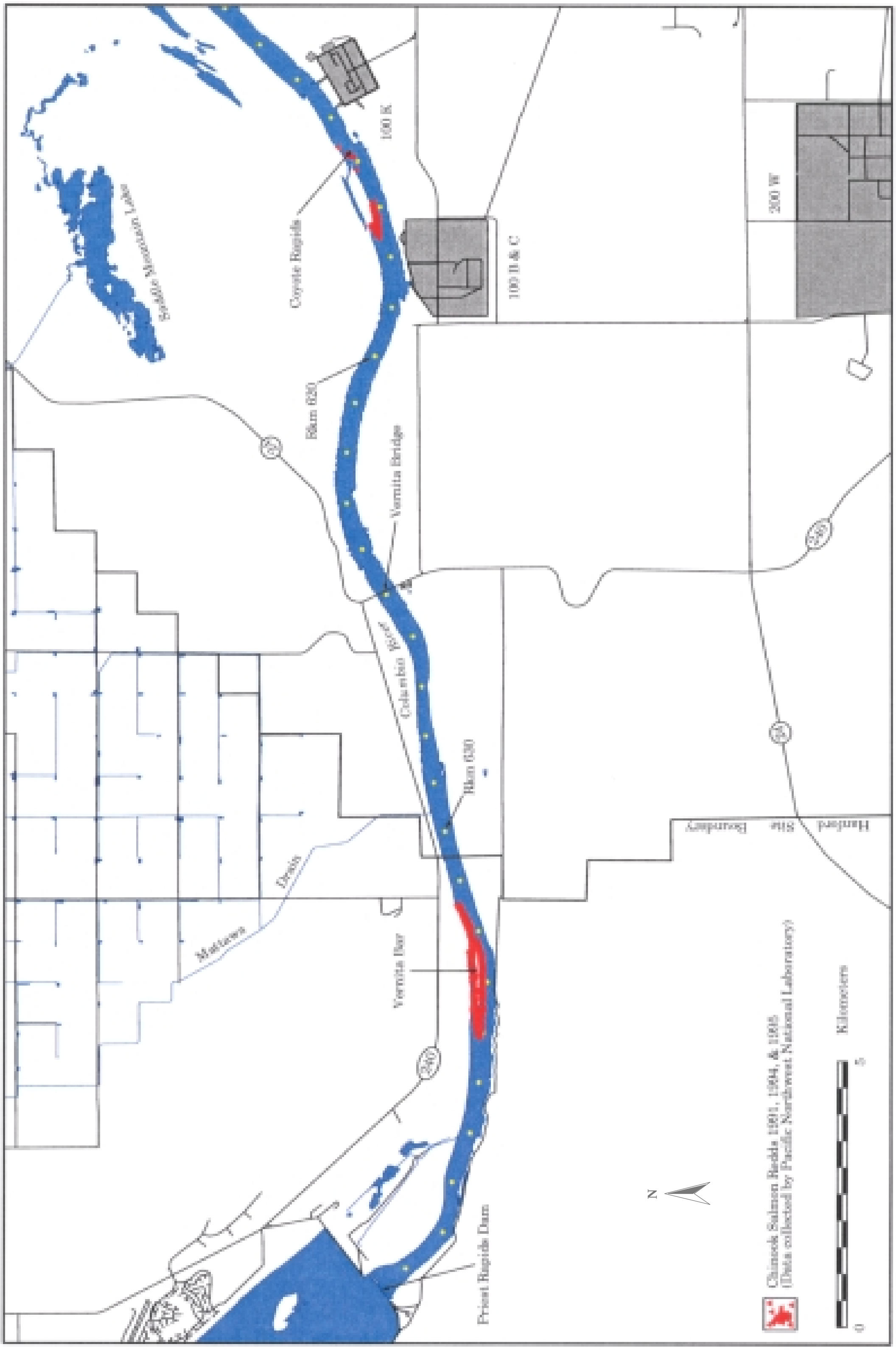

Figure 2. Plan view of the Hanford Reach of the Columbia River from Priest Rapids Dam to Coyote Rapids.

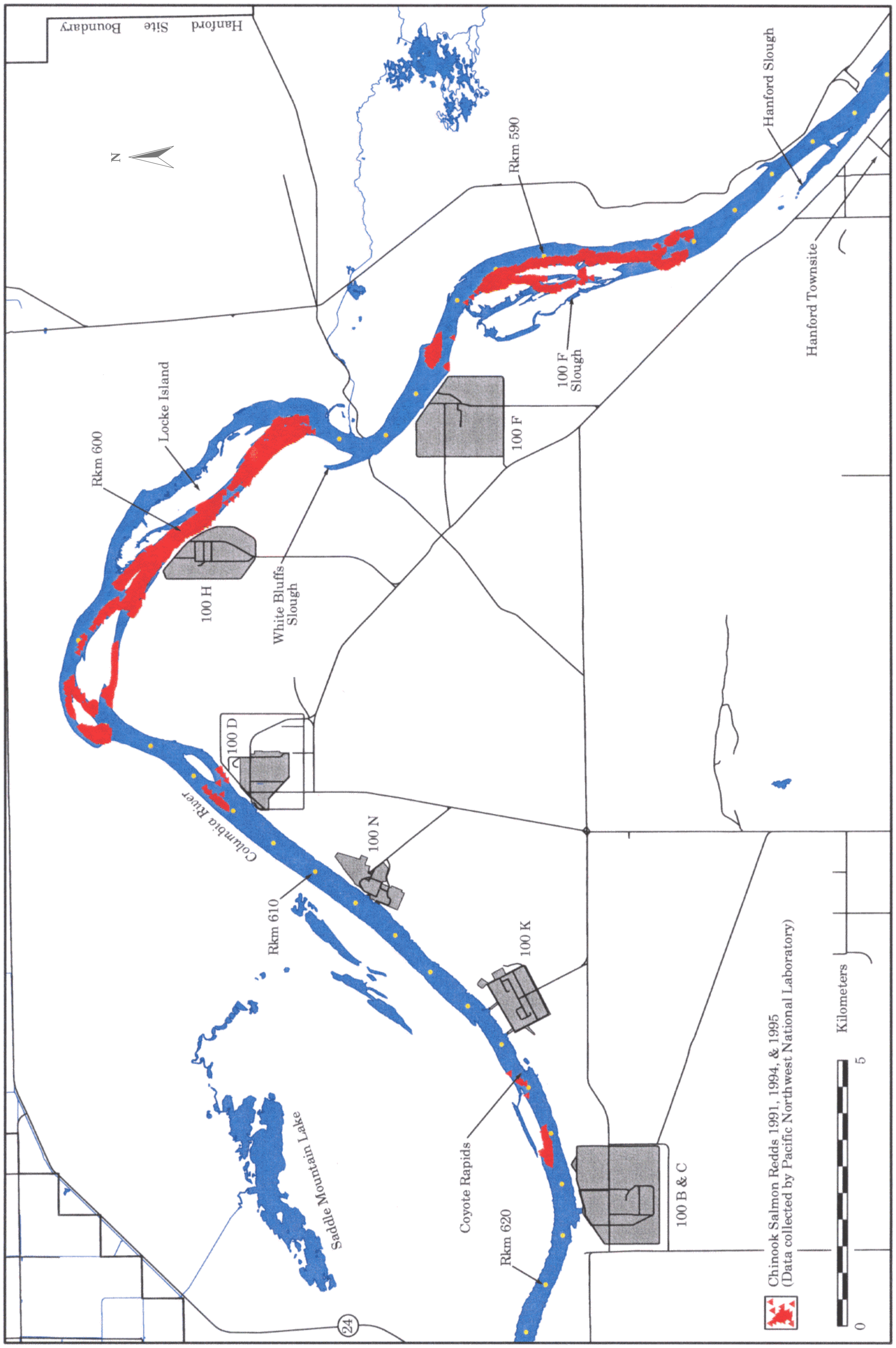

Figure 3. Plan view of Hanford Reach of the Columbia River from Coyote Rapids to Hanford Slough.

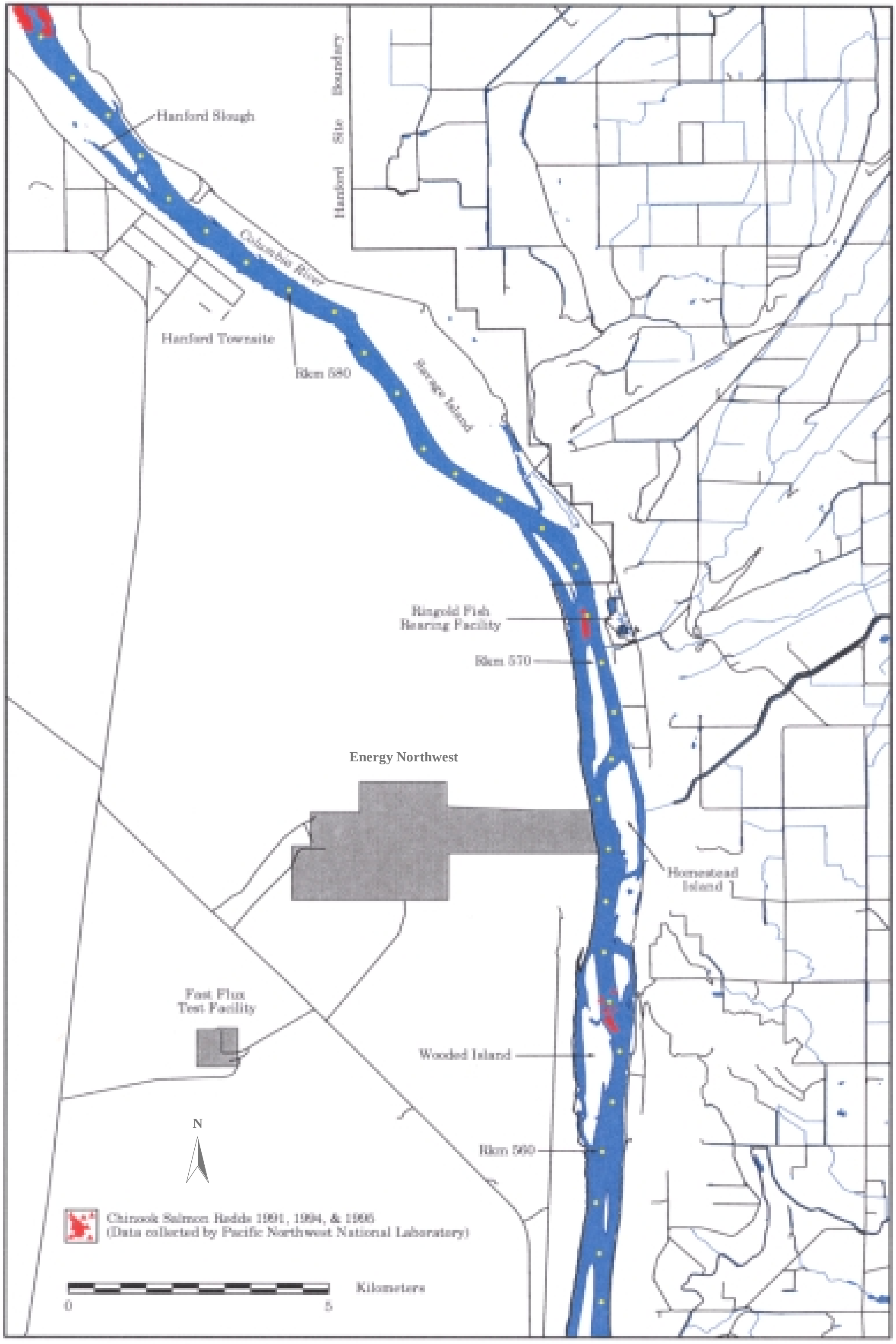

Figure 4. Plan view of Hanford Reach of the Columbia River from Hanford Slough to Richland.

Below Savage Island the river turns to the south. Unconsolidated bluffs on the eastern bank and sand dunes and steep embankments on the western bank dominate this final section of the Hanford Reach, from the bottom of Savage Island to the top of the McNary Pool in Richland. The river channel is incised and straight and island formation appears restricted by the river channel. Braiding is less pronounced than in upper stretches of the river providing less gravel bar and backwater areas. Fall chinook salmon spawning occurs at the top of the main channel island adjacent to the Ringold fish hatchery (Rkm 570.5) and near Wooded Island (Rkm 561.6).

Climate

The Hanford Reach, situated in the rain shadow of the Cascade Mountain Range, receives an annual mean precipitation of 16.1 cm and is considered mid-latitude semi arid (Glantz et al. 1990). Most of the precipitation falls between October and May (Rickard 1988). Summers are warm and dry with temperatures often exceeding 38^{o}C (Glantz et al.1990). Winters are cool with occasional precipitation and outbreaks of cold artic air that can drop temperatures below –18^{o}C (Glantz et al.1990).

During the juvenile fall chinook salmon emergence and rearing period (March – June) average maximum temperatures range from 14.1^{o}C in March to 28.8^{o}C in June. Average minimum temperatures range from 1.1^{o}C in March to 12.9^{o}C in June. Precipitation averages 4.5 cm during the juvenile fall chinook salmon emergence and rearing period. Large diurnal temperature contrasts can occur during this time period due to low relative humidity in combination with intense solar radiation during the day and radiational cooling at night (Hanford Meteorological Station, PNNL 1998).

River Dynamics

The Hanford Reach is the last free flowing section of the Columbia River above Bonneville Dam. River flows through the Hanford Reach are influenced by seven projects, Grand Coulee, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids. The Upper Columbia projects below Grand Coulee have limited storage capacity. The flow fluctuations observed in the Hanford Reach are largely set by upstream operations at Grand Coulee so that the goal of the juvenile fall chinook protection program is to reshape these fluctuations and minimize their impact on the Hanford Reach.

Daily fluctuations in river elevation on the Hanford Reach can vary significantly on an hourly basis. Historically, under normal project operations, tailwater reductions in excess of 7 vertical ft/hr (2.1 m/hr) and 13 vertical ft (4.0 m) within a 24-hr period have occurred during the juvenile fall chinook salmon emergence and rearing period.

Seasonal daily average discharges from Priest Rapids Dam range from about 40 to 250 kcfs (Dauble and Watson 1997). Average seasonal flows from 1989 to 1998 show that spring runoff peaks during mid-June and decreases significantly during the summer with annual minimum flows in September **(Figure 5**). The Federal Energy Commission has established 36 kcfs as a minimum flow from Priest Rapids Dam (Dauble and Watson 1997).

Fluctuations in river elevation downstream of Priest Rapids Dam are dampened by channel configuration and bank storage. Translation time of fluctuations downstream is determined by a variety of factors that may include river configuration, bank storage, and magnitude and duration of the fluctuation.

The Hanford Reach has no natural tributaries and receives little additional influent from other sources. Sources of influent include irrigation wastewater returns and several small streams that have developed from increase agricultural activities and groundwater discharge.

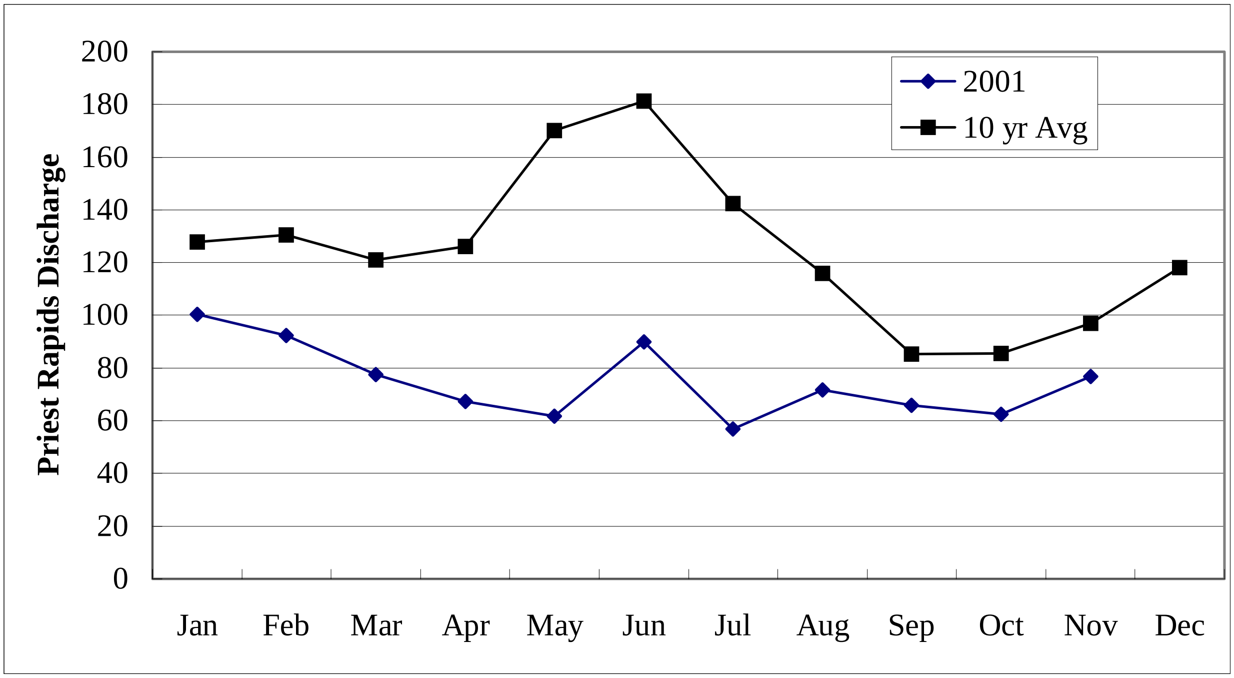

Figure 5. Comparison of mean monthly flows in 2001 versus 10-year average (1991 – 2000) for the Columbia River below Priest Rapids Dam.

Objectives

The specific objectives of the year 2001 evaluation work will be to:

1) Determine the starting and ending dates of the special operations period.

2) Estimate the number of wild juvenile chinook A) killed and B) placed at risk within the 17 mile designated sampling area during the special operations period.

3) Evaluate the impact on wild juvenile chinook of flow conditions and protection measures recommended by the Hanford Stranding Policy Group during the special operations period.

4) Determine through daily monitoring the need for emergency re-wetting during the special operations period.

5) Test and refine the juvenile fall chinook susceptibility model developed by PNNL

6) Define the relationships among habitat, physical, and biological variables on stranding susceptibility.

Methods

Objective 1

Determination of the starting date for the year 2001 special operations plan will be based upon chinook counts from six in-river index sites. Field surveys will begin approximately one week prior to the start of chinook emergence as calculated by GCPUD staff as part of the Vernita Bar Settlement Agreement. Note that start of emergence as defined under the Vernita Bar Settlement Agreement is for protection of pre-emergent chinook at flow elevations of 36 kcfs (minimum project discharge) or greater. The one-week variance is to provide protection if emergence is earlier than predicted. WDFW staff will seine six predetermined index sites once every other day until a cumulative total of 50 chinook are captured in a single day. WDFW staff will continue to seine the six index sites once per week through June 30. Termination of special operations will occur when 400 temperature units Celsius (TUs) has accumulated after the estimated end of emergence as determined by the Vernita Bar agreement or by agreement from the Hanford Reach Stranding Policy Group.

Objective 2

Detailed bathymetry data was collected in 1998 for a 17 mile section of the Hanford Reach (RM 360 to RM 377) encompassing flow elevations from 36 kcfs to 400 kcfs. This information was incorporated into a GIS and coupled with the Unsteady Flow Model (MASS1, see Nugent 2001). This allowed model simulation (within the 17 mile section previously described) of the total surface area unwatered as a result of flow reductions. With the use of the GIS model, this area was subdivided into 3600 ft^2 circular cells or sampling units. Sample cells were randomly drawn from these sampling units.

Per the sampling protocol established in 1999, hourly flow data from the Priest Rapids Project was reviewed prior to the start of each sampling day to determine the flow fluctuation area and the appropriate cells to be sampled. Two boat crews conducted sampling of the 17 mile area daily throughout the special operations period. The crews used GIS generated maps to guide them to the general vicinity of each target sample cell and a GPS to determine the specific cell location. A marker (anchor) was placed at the center of the circular cell and a pre-measured length of cable was used to define the circle circumference of the sample cell. Specific data collected from 3600-ft^2 sample cells consisted of:

1) numerical counts of all stranded/entrapped chinook. Chinook were removed from entrapments with stick seines or hand nets. Live and dead fish were recorded separately in the direct counts. Excavation of cobble substrate or removal of heavy vegetation from sub-sample plots was necessary to measure stranding in areas where direct visual observations could not be made.

2) water temperature of entrapment areas. This data was collected to reference thermal stress related mortality rates.

3) fork lengths of stranded/entrapped chinook. This data will be collected to reference size and susceptibility to stranding/entrapment.

4) substrate composition, embeddedness, and vegetation composition consistent with the criteria established during the first three years of work.

5) predator activity. Predator activity consisted of tracks in the substrate within the sampling site or direct observation of piscivorous or avian presence.

In addition, once per week baseline chinook population structure was determined by standardized sampling of nearshore areas in the six established index sites. Chinook were sampled from these areas with a 70-foot beach seine. One seine set per index site was conducted and all chinook were counted. Sub-samples of the chinook collected were measured to determine length frequency distribution. The location of the six index sites was the same as those used in 2000. PNNL staff provided all statistical analysis of estimation of juvenile fall chinook “at risk” and mortality in year 2001 based on data collected from the random sample cells.

Objective 3.

Assessment of the impacts of fluctuations of project discharge on juvenile fall chinook survival and evaluation of the 2001 Juvenile Fall Chinook Protection Plan is based on comparative results of 2001 chinook mortalities and at risk to previous years losses. Chinook mortality and at risk was determined through random sampling of the flow fluctuation zones from daily operations as discussed in Objective 2.

Objective 4.

A third crew was deployed throughout the special operations implementation period to determine the daily need for emergency re-wetting. Index entrapments were monitored daily. Chinook within the index entrapments were counted and returned to the river. Water temperature and entrapment drainage rate were measured during the course of the day (8:30 am – 3:30 pm). When lethal conditions (imminent drainage or lethal temperature) within chinook entrapments and increased chinook losses in random samples was observed, the WDFW and GCPUD designated personnel were contacted to determine if Priest Rapids outflows should be increased to reduce mortality impacts.

This work was combined with that of objective 3 and that the third crew indicated above conducted work under objectives 3 and 4 concurrently each day at a designated index area.

Objective 5.

Battelle continued work on a juvenile fall chinook susceptibility model for predicting the number of juvenile fall chinook salmon 'at risk' (i.e., stranded) as a result of changes in system operations.

Objective 6.

Battelle worked with WDFW on investigations into relationships among habitat, physical and biological variables, and stranding susceptibility. This effort will include existing and FY 2001 data (see attached PNNL work plan, Task 2).

Estimates of Juvenile Fall Chinook Salmon Stranding and Entrapment

A sampling plan was designed by PNNL and WDFW prior to the field season to estimate the total number of juvenile fall chinook salmon killed or placed at risk due to flow fluctuations during the implementation of the 1999 Interim Protection Program. The plan was developed for the portion of the Hanford Reach defined by the SHOALS bathymetry data from 40 to 400 kcfs.

The study area was classified into 40 kcfs flow bands and divided into 3600 ft^2 (344.4 m^2) plots or sampling cells. The sample plot size was based on the mean size of entrapments found in 1998. Sample plots that crossed the line between designated 40 kcfs flow bands were included in the flow band that contained at least 50% of the cell. Cells that did not include a majority of one 40 kcfs flow band were removed from consideration. A list of all cells contained within the study area was compiled and cells were randomly selected to use in daily field sampling activities described in the preceding section. Daily sampling targeted wetted flow bands identified in the previous 48-hour flow history.

Initiation of field activities was based upon juvenile fall chinook salmon emergence timing as calculated under the terms of the 1988 Vernita Bar Settlement Agreement. Because fall chinook salmon spawning and subsequent spring emergence may occur earlier than predicted, field operations were initiated approximately one week prior to the calculated start of emergence to ensure maximum protection of newly emergent fall chinook salmon. Implementation of the 2001 Protection Program and field sampling was based on population surveys conducted at six index sites. Detailed information regarding the 2001 Interim Protection Program initiation criteria is included in **Appendix A**.

Two field teams comprised of WDFW and GCPUD personnel collected data daily during the fall chinook salmon emergence and rearing period when wetted shorelines were visible. The crews chose sample locations in the appropriate flow bands from the list of randomly generated sample plots prior to sampling. A high-performance global positioning system (GPS) with submeter accuracy was used to navigate to the sample locations.

An anchor attached to an incrementally marked cable was placed at the center of each sample plot to delineate the circular boundary of the plot. The number of juvenile fall chinook salmon and other species of fish found within the sample plot were counted and classified as alive or dead. If entrapments were encountered, an assessment was made to determine the percentage of the entrapment contained within the sample plot. Entrapments with area of 50% or greater within the circle were sampled in their entirety. Entrapments with area of greater than 50% outside of the circle were not surveyed. In cases where portions of the plot were dry or under water at the river's edge, the marked rope was used to measure the amount of wetted shoreline. A scaled drawing was produced to calculate the proportion of the plot contained within the fluctuation zone. Other data recorded at the sites included bird activity (i.e., tracks), entrapment water temperatures, dominant and subdominant substrate size, substrate embeddedness, and vegetation density. Dominant and subdominant substrate size were classified according to a modified Wentworth code (Platts et al. 1983); substrate embeddedness was classified according to Platts et al. (1983); and vegetation density was recorded as absent, sparse, medium, or dense (**Appendix B**). Methods for calculating the estimated total number of juvenile fall chinook salmon mortalities and at risk due to stranding and entrapment are provided in **Appendix D**.

Fall Chinook Salmon Fry Production Estimate

A coarse estimate of the 2001 fall chinook salmon fry production in the Hanford Reach was calculated to gauge the proportion of the population affected by flow fluctuations. No studies have been conducted on egg to emergence/fry/smolt mortality rates of fall chinook salmon on the Hanford Reach. The estimate was based on 2000 adult fall chinook salmon escapement to the Hanford Reach, number of spawning females, fecundity, egg retention, and egg to emergence/fry/smolt mortality. Information on escapement, number of spawning females, and egg retention was obtained from the 2000 WDFW Hanford Reach carcass and creel surveys (Watson 2001). The sex composition of Hanford Reach spawners was derived from the sport fishery harvest data collected during these surveys (**Appendix E**). It was assumed that anglers had an equal chance of harvesting a male or female and there was no behavioral characteristics associated with gender that would bias catch. Fecundity rates have not been established for naturally spawning fall chinook salmon on the Hanford Reach but, for this estimate, it was assumed that these rates were similar to rates of females sampled at Priest Rapids Hatchery. Mortality rates used in this estimate were selected from a compilation of other studies gathered by Healey (1998) (**Appendix E**). The mean mortality rates reported in three studies of natural spawners that were not influenced by flood events or controlled flows were used in this estimate. The studies included one from California (Wales and Coots 1954) and two from British Columbia (Lister et al. 1971, Healey 1980).

Assessment of Juvenile Fall Chinook Salmon Relative Abundance and Fish Size

Juvenile fall chinook salmon were seined from six nearshore sampling sites on the Hanford Reach once a week during the emergence and rearing period to assess relative abundance and fish size. The six sites included three at Locke Island (Rkm 597.0, 599.5, and 600.7), one upstream of 100 F Islands (Rkm 593.1), one at 100 F Islands (Rkm 591.4), and one at the downstream end of Savage Island (Rkm 573.2). Seining techniques were similar to methods described by Key et al. (1994).

A beach seine, 21.3 m x 1.8 m with a 1.8 m^2 bag, 4.8 mm diamond mesh, and 15.2 m leads, was used to collect juvenile fall chinook salmon and other fish species from the six designated nearshore sampling sites. One lead of the seine was cleated to the bow of a 5.5 m boat, the seine was folded and laid on the bow, and the other lead was held by a person on shore. The boat was then backed perpendicular to shore to a distance of 15.2 m and then backed upstream allowing the seine to be fed out parallel to shore. Once the seine was deployed, the boat was maneuvered back into shore. Both ends of the seine were then simultaneously hauled to shore. The area sampled in this manner was approximately 320 m^2. When samples contained less than 40 juvenile fall chinook salmon, all fish were anesthetized with tricaine methanesulfonate (MS 222), measured, and fork lengths were recorded. Samples containing over 40 juvenile fall chinook salmon were sub-sampled to obtain approximately 30 fish. Fish sub-sampled were anesthetized and fork lengths were recorded; the remaining fish were counted. All fish were released back into the river. Temperature, dominant and subdominant substrate size (modified Wentworth code; Platts et al. 1983), substrate embeddedness (Platts et al. 1983), and vegetation density (absent, sparse, medium, or dense) were recorded for each site (**Appendix B**).

Evaluation of Potential Mortality Events in Primary Fall Chinook Salmon Rearing Areas

An emergency management team (EMT) consisting of WDFW personnel monitored primary fall chinook salmon rearing areas for potenial mortality events. The objective of the EMT was to identify flow fluctuation events that posed risks to large numbers of juvenile fall chinook salmon. When such events were identified, a pre-established notification procedure was used to request immediate corrective action.

The EMT inspected one of three sites daily. The sites included Locke Island (Rkm 600.0), 100 F Islands (Rkm 591.0), and Wooded Island (Rkm 562.0). The EMT alternated through these sites in consecutive order. Observation entrapments were established at each of the sites and used to index conditions throughout the Hanford Reach. Multiple entrapments were identified and marked at each site so that the full range of flow conditions could be indexed. When entrapments containing juvenile fall chinook salmon were observed, all fish were seined, counted, and released into the river. After removal of the fish, water temperatures and drainage rates were monitored in the entrapments throughout the day. If two or more entrapments previously containing juvenile fall chinook salmon reached 24ºC or drainage of the entrapments was imminent, the EMT would contact the other field crews to verify that similar detrimental conditions were present in other areas of the Hanford Reach. When conditions warranted, the field crew leader would call the designated GCPUD personnel to request immediate re-wetting or other operational solutions.

Modeling of Juvenile Fall Chinook Salmon Susceptibility to Stranding and Entrapment

PNNL has been subcontracted to provide a juvenile fall chinook salmon susceptibility model for the Hanford Reach. The model will be developed to examine and evaluate flow reduction scenarios and associated juvenile fall chinook salmon mortality. Integration of prior and subsequent years data will be used to complete the model. The data to be incorporated includes detailed river bathymetry (SHOALS data), the unsteady flow model (MASS1), biological data such as emergence timing, population structure, fish size and rate of growth, as well as other physical habitat parameters including, water temperature, substrate size, substrate embeddedness, and vegetation density.

Results

This section of the document provides a description of the 2001 Hanford Reach conditions and a compilation of the results of the 2001 evaluation.

2001 Hanford Reach Flows and Meteorological Conditions

River and meteorological conditions on the Hanford Reach during the 2001 juvenile fall chinook salmon emergence and rearing period (March–July) were marked by, near normal ambient air temperatures and precipitation, above average solar radiation levels, and extremely low river flows (**Table 1**).

Air temperatures were near normal during the 2001 juvenile fall chinook salmon emergence and rearing period. Mean monthly air temperature was slightly cooler in April (-1.1ºC) and June (-1.5ºC) and above normal in May (+1.0ºC) (Hanford Meteorological Station, PNNL 2001). Precipitation during March through July was slightly higher in April and June and lower in May and July. Solar radiation levels, a good indication of cloud cover, were below normal for all months except May and well below normal for April. Hourly river temperature was recorded in 2001 and is illustrated in **Figure 6** for March 26 through July 31. River temperatures warmed on average 1ºC daily from March 26 through June 30 with a maximum increase during this period of 1.6ºC.

River temperature averaged 11.2ºC from March 26 through June 30 with a peak temperature of 16.7ºC on June 30. Mean monthly river temperatures in 2001 were above the 9-year means (1992-2000) for January through June. Mean river temperature for May was well above the 9-year mean as would be expected with decreased flows, increased air temperatures, decreased precipitation, and increased solar radiation.

Comparison of 2001 river flows to 10-year mean flows (1991-2000) indicates that 2001 was well below average for all months. Juvenile fall chinook were most susceptible to stranding/entrapment from March 21 through June 10 in 2001. Priest Rapids Project discharges averaged 70.9 kcfs during this period. Hourly discharge from the Project ranged from 37.5 kcfs to 152.2 kcfs (**Figure 7**). Mean daily fluctuation during the Protection Program (March 26 – June 10) was 23.2 kcfs, range 0.7kcfs–84.5kcfs[1] (**Figure 8**).

---

[1] A 17 kcfs increase or decrease in discharge equates to a vertical change in river elevation of approximately one foot at Vernita Bar. This change in elevation is reduced at locations downstream.

Mean daily flow fluctuation from Priest Rapids Dam during the critical period of susceptibility (March 21 – May 27) was 17.6 kcfs, range 0.7 – 77.9 kcfs (**Table 2**). On 48 of the 68 days occurring during the critical susceptibility period, flows were relatively stable (fluctuations < 20 kcfs). Daily fluctuations above 40 kcfs were recorded on 14 days and two of these days were prior to the beginning of the Protection Plan. From May 28 through June 10, mean daily flow fluctuation was 50.4 kcfs, range 25.5 – 84.5 kcfs.

Table 1. Comparison of 2001 monthly average river flow, river temperature, air temperature, precipitation, and solar radiation level to past years on the Hanford Reach of the Columbia River.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
River Flows[1] (kcfs)												
2001	100.4	92.4	77.6	67.2	61.8	90.0	56.8	71.6	65.8	62.4	76.7	-
Mean (1991-2000)	127.9	130.5	121.1	126.2	170.1	181.4	142.4	115.8	85.3	85.4	97.0	118.1
Departure	-27.5	-38.1	-43.5	-59.0	-108.3	-91.4	-85.6	-44.2	-19.5	-23.0	-20.3	-
River Temperatures[1] (°C)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2001	4.0	3.1	5.0	7.6	12.2	14.6						
Normal (1992- 1999)	3.7	3.0	4.4	7.3	10.5	13.8						
Departure	+0.3	+0.1	+0.6	+0.4	+1.7	+0.8						
Air Temperature[2] (°C)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2001	0.8	2.1	8.2	10.8	17.6	19.2	24.4	25.4	20.6	11.9	6.0	-
Normal (1971-2000)	-0.1	3.3	7.8	11.9	16.6	20.7	24.6	24.1	18.8	11.7	4.5	-0.2
Departure	+0.9	-1.2	+0.4	-1.1	+1.0	-1.5	-0.2	+1.3	+1.8	+0.2	+1.5	-
Precipitation[2] (cm)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2001	0.7	1.1	1.7	2.1	0.5	3.2	0.1	0.2	0.3	0.9	4.2	-
Normal (1971-2000)	2.2	1.7	1.5	1.1	1.4	1.0	0.7	0.7	0.8	1.2	2.5	2.8
Departure	-1.5	-0.6	+0.2	+1.0	-0.9	+2.2	-0.6	-0.5	-0.5	-0.3	+1.7	-
Solar Radiation[2] (Langleys)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2001	74.7	192.4	287.5	330.5	525.1	522.4	570.6	495.7	378.6	209.6	85.7	-
Mean (1980-2000)	95.5	169.1	299.3	425.6	518.1	576.6	601.5	523.0	387.8	241.3	115.5	75.3
Departure	-20.8	+23.3	-11.8	-95.1	+7.0	-54.2	-30.9	-27.3	-9.2	-31.7	-29.8	-

[1]Data from USGS Gauging Station 12472800 below Priest Rapids Dam

[2] Data from Hanford Meteorological Station, PNNL

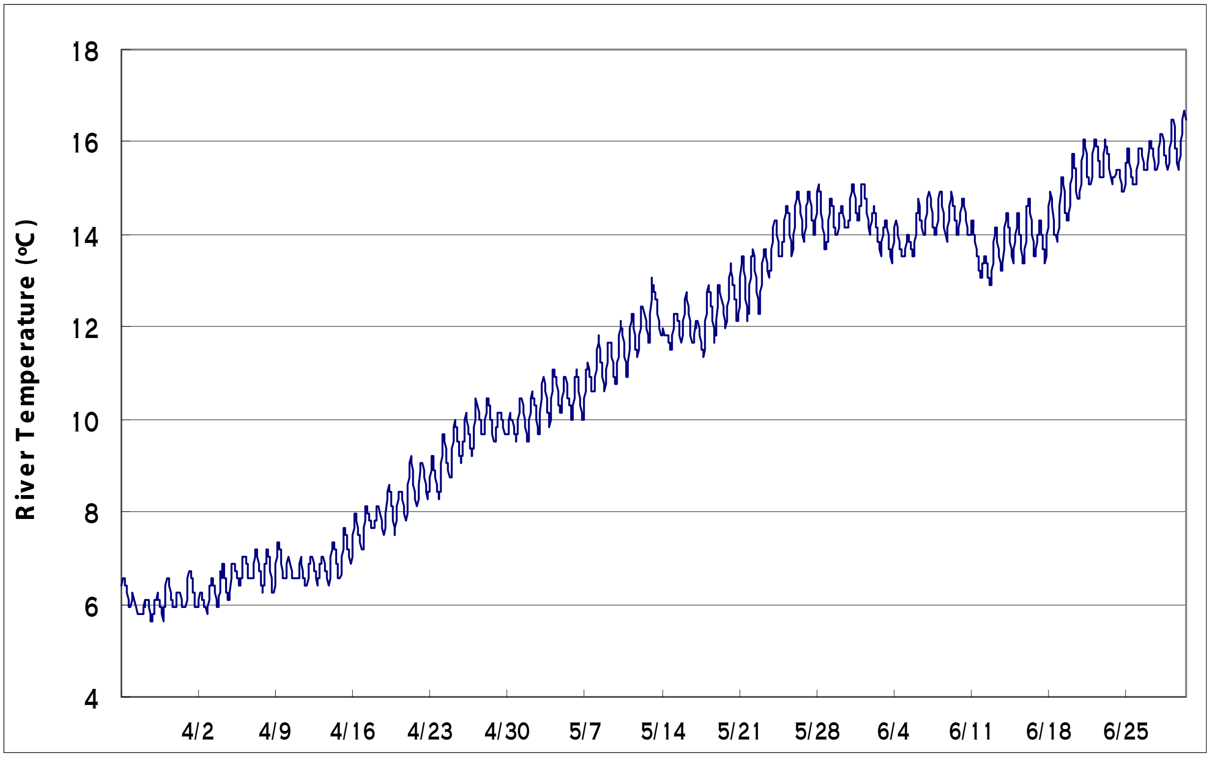

Figure 6. Hourly river temperatures at White Bluffs area of the Hanford Reach , March 26 – June 30, 2001.

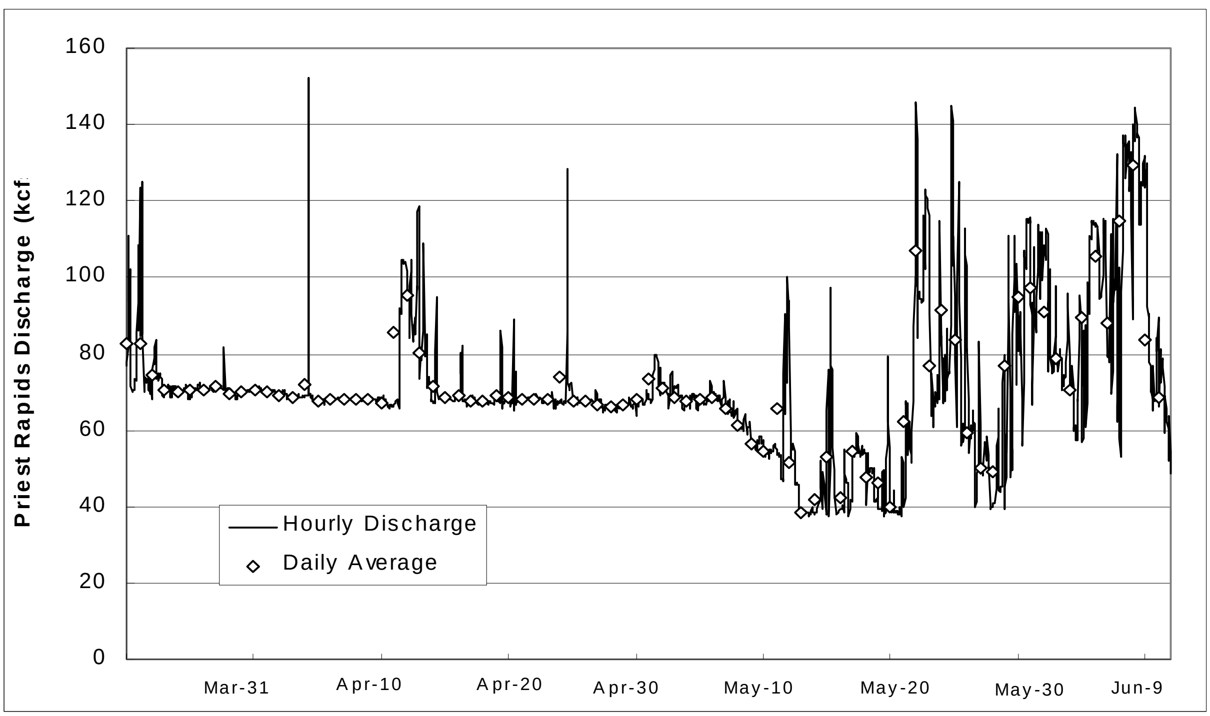

Figure 7. Hourly discharge and average daily flows from Priest Rapids Dam, March 21 – June 10, 2001.

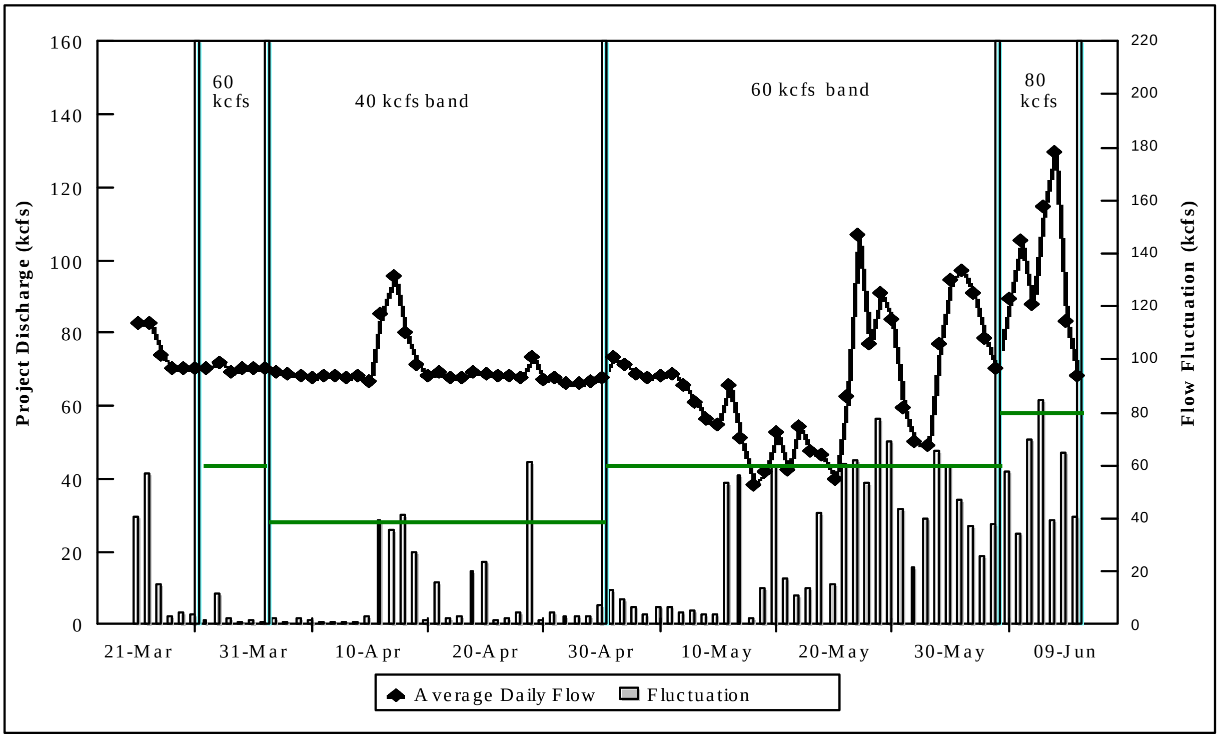

Figure 8. Average daily flows, daily fluctuation in discharge, and Protection Plan constraints for Priest Rapids Dam, March 21 – June 10, 2001.

Table 2. Daily fluctuations in discharge from Priest Rapids Dam, March 21 – June 10, 2001.

Daily Fluctuation (days)	Mean (kcfs)	< 20kcfs (stable)	20-40kcfs	40-60kcfs	60-80kcfs	>80kcfs
Mar 21 – May 27	17.6	48	6	9	5	0
May 28 – June 10	50.4	0	5	5	3	1
Total	23.2	48	11	14	8	1

Implementation Timing and Operation of the 2001 Hanford Reach Juvenile Fall Chinook Salmon Interim Protection Program

All aspects of the interim protection program are subject to evaluation and modification during each year of the evaluation. A working interim protection program has been agreed upon by the Hanford Policy Group each year since the inception of an operation program in 1999. The 2001 Protection Plan was designed to provide a high level of protection for rearing fall chinook fry, maintain reasonable load following capability at all 7 projects, conduct monitoring and evaluation that allows evaluation of the program relative to its effect on entrapment and stranding, and provide a monitoring program that allows in-season changes of operations if substantial mortality is detected.

The Protection Plan set weekly constraints for flow fluctuations that would maintain protection for fall chinook and provide flexibility to Project operations based on susceptibilility as determined from the 1999 and 2000 studies (**Table 3** & **Appendix A**). Week 1 fluctuations would allow daily fluctuations of 60 kcfs. During weeks 2 through 5 daily fluctuations would be limited to 40 kcfs to coincide with the period of peak emergence, abundance, and susceptibility. In week 6, allowable fluctuations would be increased to 60 kcfs. Criteria for flow fluctuations during weeks 7 and 8 were determined based on in-season losses of chinook through week 5. Based on the data, flow fluctuations were maintained at 60 kcfs (**Appendix C**). Week 9 through the end of the Protection Plan flow fluctuations would be constrained to 80 kcfs.

In 2001, index seining (6 standard beach seine hauls at pre-determined locations) would begin one week prior to the calculated start of emergence under the Vernita Bar Agreement. Index seining would be conducted daily to define the beginning of susceptibility. Implementation of the protection program would begin when a daily total of 50 or more subyearling chinook were sampled from the 6 index seining locations. The Protection Plan would end when 400 temperature units Celsius had accumulated after the estimated end of emergence. In 1999, the last randomly sampled stranded fish was found at 379 TUs C post end of emergence and similarly in 2000 at 350 TUs post calculated end of emergence. Based on this data, the criteria of 400 TUs post emergence was used in 2001.

Emergence of wild juvenile fall chinook salmon in 2001, as calculated under the terms of the 1988 Vernita Bar Settlement Agreement (GCPUD 1988), was estimated to start on April 1 (**Figure 9**). Population index surveys were subsequently initiated on March 21 to account for possible early emergence. Criteria for implementation of the 2001 Interim Protection Program was reached on March 21 and the protection program began March 26. The first random sample was not initiated until April 13. Random sampling was not conducted as there were no significant fluctuations until April 12. The protection program ended on June 10 and evaluation field activities were continued through June 28.

Table 3. 2001 Protection Plan weekly constraints for flow fluctuations for Priest Rapids Dam.

Schedule	**Date**	**Fluctuation**
Week 1	March 26 – April 1	60 kcfs
Week 2	April 2 – 8	40 kcfs
Week 3	April 9 – 15	40 kcfs
Week 4	April 16 – 22	40 kcfs
Week 5	April 23 – 29	40 kcfs
Week 6[1]	April 30 – May 6	60 kcfs
Week 7	May 7 - 13	60/80 kcfs
Week 8	May 14 - 20	60/80 kcfs
Week 9	May 21 – End of Program	80 kcfs

[1] Following the fifth week of the program, the WDFW will report the results of random site monitoring for the first six weeks of the program. If the 85% upper confidence limit for the total impact at week six is less than the average of the estimated total impact after five weeks in 1999 and 2000, then the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 80 kcfs for the seventh and eighth weeks of the program.

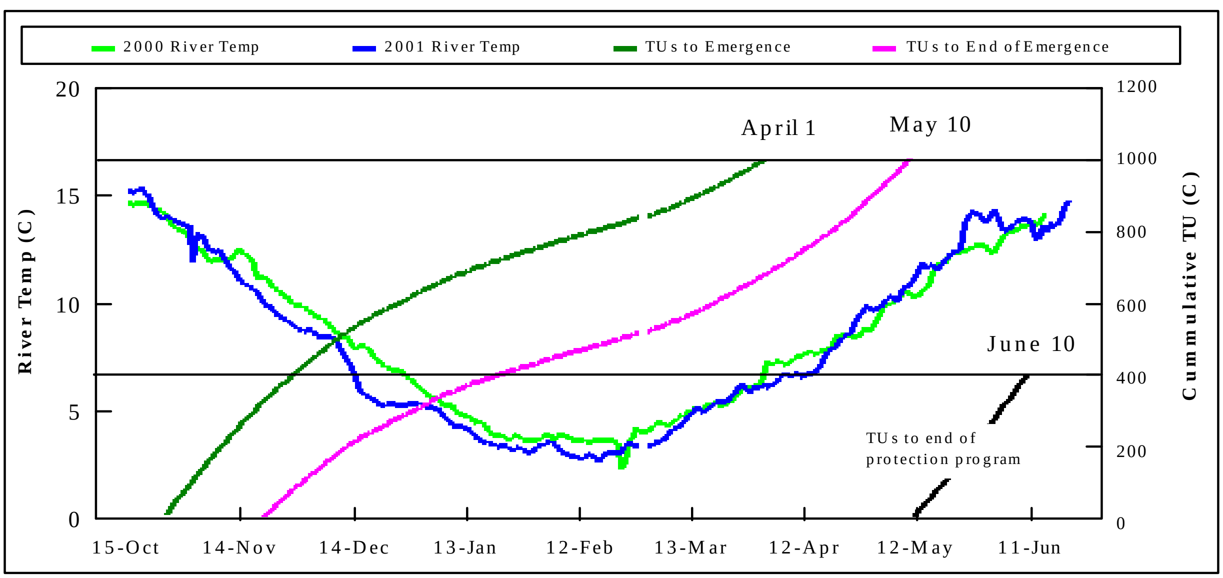

Figure 9. Mean daily river temperature for the Hanford Reach, spawning, emergence, and Protection Plan cumulative temperature units (TUs).

Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) Bathymetry Data

COE collected detailed SHOALS bathymetry data in 1998 on 35.1 km^2 of the Hanford Reach from Rkm 571.3 to Rkm 606.9 (**Figure 10**). These data were used in conjunction with MASS1 unsteady flow model to provide information on the Hanford Reach at a range of stage discharges. From this information, the extent of area of shoreline exposed by flow fluctuations and the configuration of the river channel could be determined. **Figure 11** shows the amount of area of shoreline within each 10 kcfs flow fluctuation zone for the portion of the Hanford Reach defined by the SHOALS data. The shoreline area exposed by flow fluctuations at lower river elevations (40kcfs – 110kcfs) is considerably larger than for fluctuations that occur in higher fluctuation zones. However, the amount of shoreline exposed increases in several of the higher flow bands (e.g., 170-180 kcfs) suggesting steep banks may give way in places to flats or flood terraces at these higher elevations. The extent of steep banks and flood terraces vary with river kilometer (**Figure 12**). This can be observed in the river cross-sections presented in **Figure 13**. The smaller amount of exposed shoreline in the 40-50 kcfs flow fluctuation in **Figure 11** may indicate the main river channel.

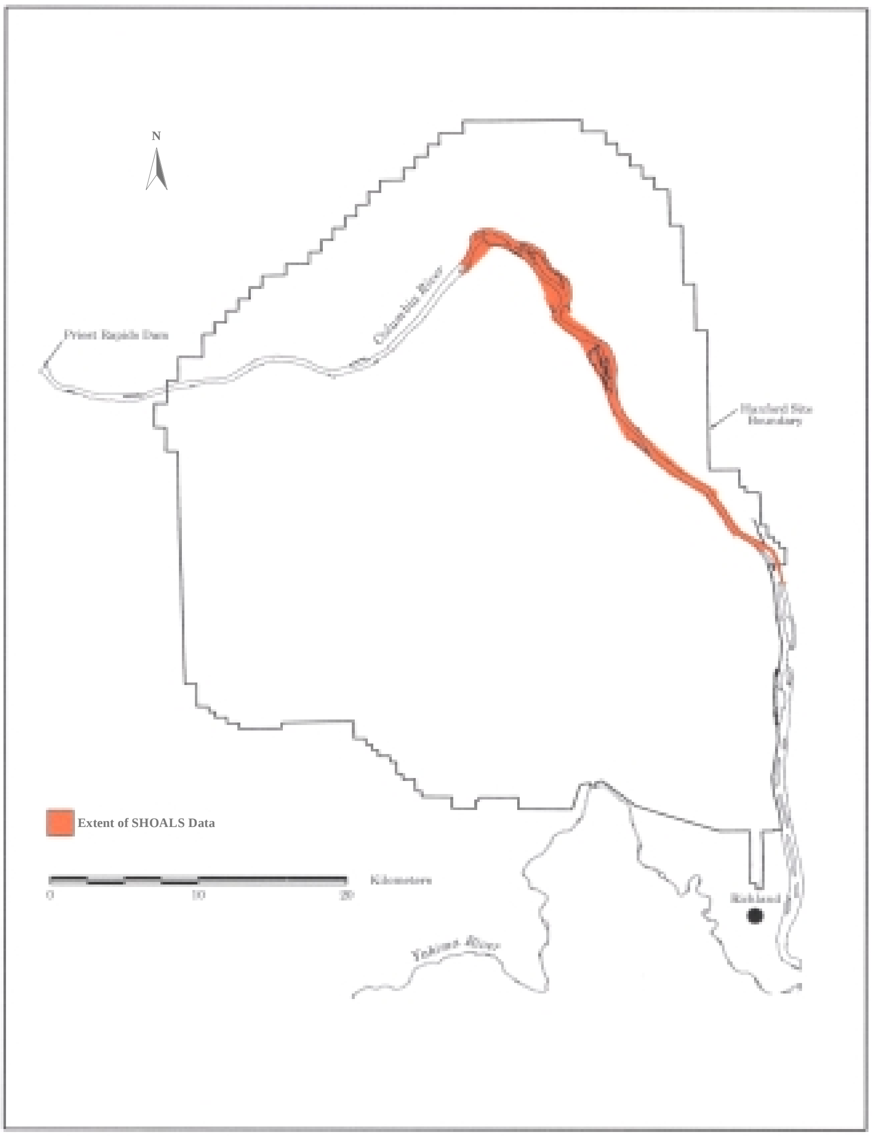

Figure 10. Area of the Hanford Reach of the Columbia River where detailed bathymetry data has been collected using the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS).

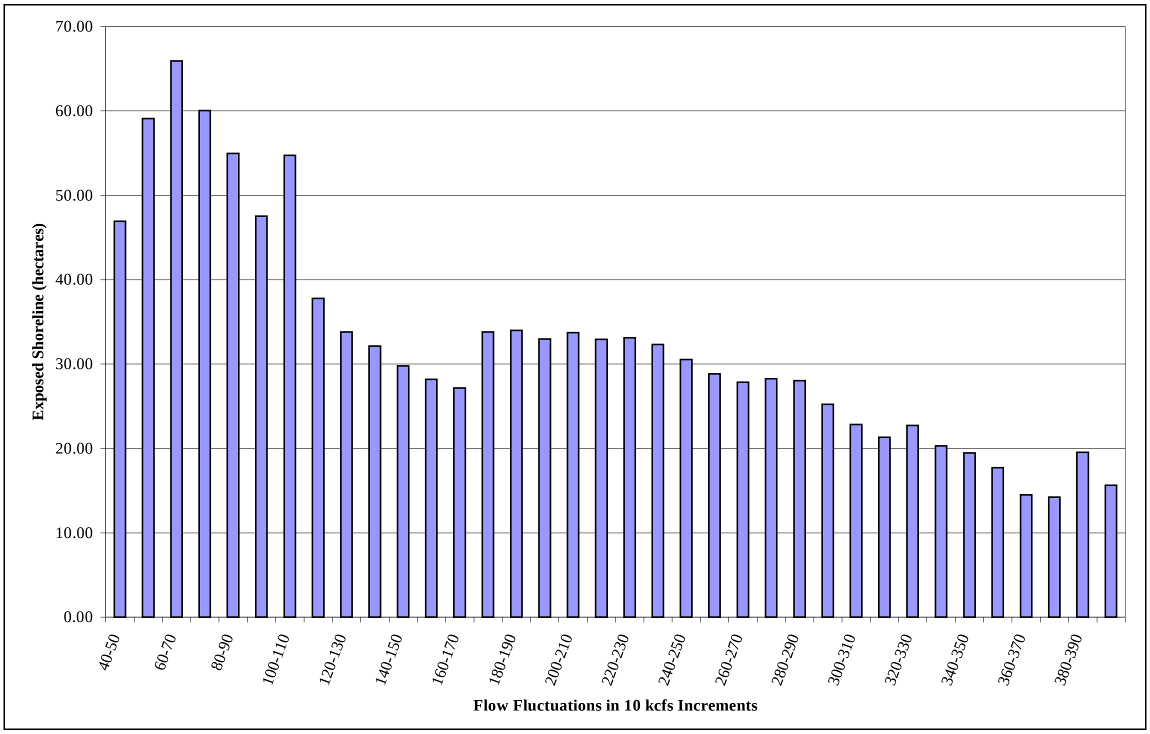

Figure 11. The area of shoreline exposed within each 10 kcfs flow band for the portion of the Hanford Reach of the Columbia River defined by the SHOALS data (Rkm 571.3 to Rkm 606.9).

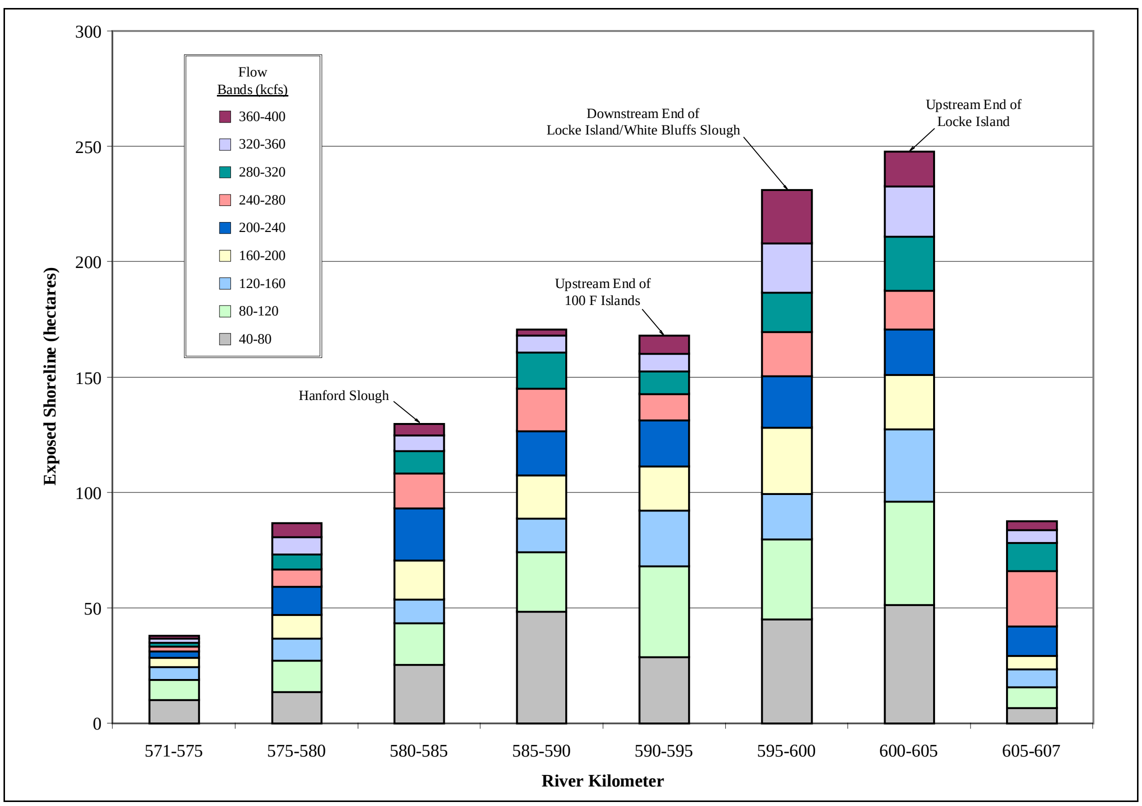

Figure 12. The area of shoreline exposed within 40 kcfs flow band for five kilometer sections of the Hanford Reach of the Columbia River defined by the SHOALS data (Rkm 571.3 to Rkm 606.9).

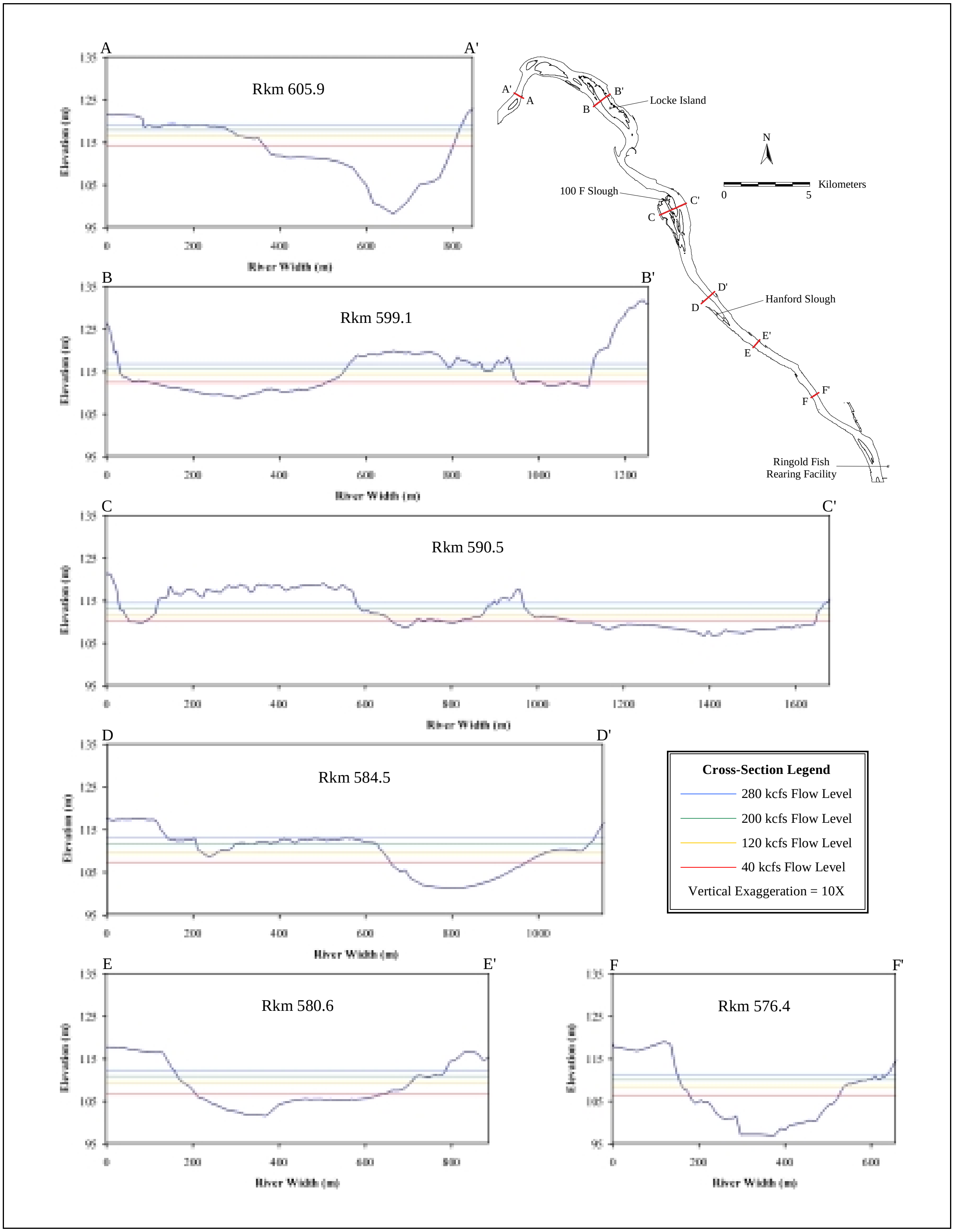

Figure 13. Cross-sectional views of the Hanford Reach of the Columbia River for the portion of the river defined by the SHOALS data (Rkm 571.3 to Rkm 606.9).

Estimates of Juvenile Fall Chinook Salmon Stranding and Entrapment

Numbers of Juvenile Fall Chinook Salmon

A total of 434 random plots encompassing 86,526 m^2 (931,388 ft^2) were sampled in 2001 between April 13 and June 28, 2001. Sampling occurred in three 40 kcfs flow bands, 40-80 kcfs, 80-120 kcfs, and 120-160 kcfs. Fish were found stranded through June 22, 2001. All samples taken during the field season were included in the estimate. The samples used in the estimates for previous years had been truncated so that samples were only included if they were taken within a week after the last stranded/entrapped fish was observed.

Flows were relatively stable through May 21 with limited fluctuations above 10 kcfs. Though few in number, fluctuations occurring during this early period of emergence and rearing often resulted in stranded/entrapped chinook. From May 6 through May 10, increased numbers of chinook were found in random plots as flows gradually decreased from 72.8 kcfs to 52.6 though no significant fluctuations occurred during this period. By May 28, chinook found in random samples had decreased though daily flow fluctuations had risen in accordance with the criteria in the protection plan indicating reduced susceptibility.

Random plots contained 3,313 juvenile fall chinook salmon in 2001. Field crews recorded 3,238 direct mortalities consisting of the 316 stranded and 2,922 thermal induced fatalities (**Table 4**). Fish were first encountered in random plots on April 13,2001 and last found on June 22, 2001. The majority of juvenile fall chinook salmon mortalities were sampled during the month of April (2,278). The estimated total number of juvenile fall chinook salmon stranding and entrapment mortalities in 2001 was calculated to be 1,628,878 with a 95% confidence interval between –286,153 and 3,543,910. Juvenile fall chinook salmon placed at risk of mortality due to stranding and entrapment was calculated to be 1,663,636 with a 95% confidence interval between –252,186 and 3,579,458 (**Appendix D**).

These assessments should be considered minimum estimates. Loss estimates are calculated for the study area only, area for which detailed bathymetry data was available, and is roughly one third of the Hanford Reach. In addition, sampling efficiency was assumed to be 100%. Potential sources of reduced sampling efficiency included losses of fish from sample locations to scavengers/predators prior to sampling and/or less than 100% efficiency in recovery of fish by surveyors during sampling activities.

Table 4. Weekly numbers of juvenile fall chinook salmon found in random plots on the Hanford Reach of the Columbia River in 2001.

Week	Stranded[1]	Entrapped[2]	Total Mortalities (Stranded + Thermal)	Total Chinook at Risk
April 8-14	3	0	3	3
April 15-21	2	69 (69)	71	71
April 22-28	257	2,016 (2,016)	2,273	2,273
April 29-May 5	0	0	0	0
May 6-12	8	905 (141)	149	913
May 13-19	26	2	28	28
May 20-26	18	1 (1)	19	19
May 27-June 2	2	0	2	2
June 3-9	1	0	1	1
June 10-16	1	0	1	1
June 17-23	1	0	1	1
June 24 -30	0	0	0	0
Total	319	2,993 (2,227)	2,548	3,312

Other Fish Species

Minimum numbers of fish other than fall chinook salmon were sampled during the implementation and evaluation of the Interim Protection Plan in 2001 (March 26 – June 28). Only eight additional species of fish were collected in random plots during sampling (**Table 5**). Resident species consisted primarily of northern pikeminnow and additionally included peamouth, lamprey, dace, redside shiner, sculpin, sucker, and threespine stickleback.

Table 5. Non-salmonid species encountered in random sampling, (March 26-June 10, 2001).

Common Name	Scientific Name	Stranded[1]	Entrapped[2]	Total Fish
Dace	*Rhinichthys* spp.	1		1
Lamprey	*Lampetra* spp.		2	2
Northern Pikeminnow	*Ptychocheilus oregonensis*	1	37	38
Peamouth	*Mylocheilus caurinus*	1	1	2
Redside Shiner	*Richardsonius balteatus*		2	2
Sculpin	*Cottus* spp.	6	4	10
Sucker	*Catostomus* spp.		2	2
Threespine Stickleback	*Gasterosteus aculeatus*		3	3
Unknown Juvenile	-	1		1
Total		10	51	61

[1] All stranded fish were counted as mortalities.

[2] No entrapped fish were found dead.

Size Susceptibility of Juvenile Fall Chinook Salmon

Juvenile fall chinook salmon collected in random plots had a mean fork length of 42.3 mm and ranged from 31 to 54 mm (**Figure 14**). All individuals sampled were less than 60 mm in length. These results are similar to data from the 1999 and 2000 evaluations and reconfirms data suggesting that juvenile fall chinook greater than 59mm have reduced susceptibility to stranding.

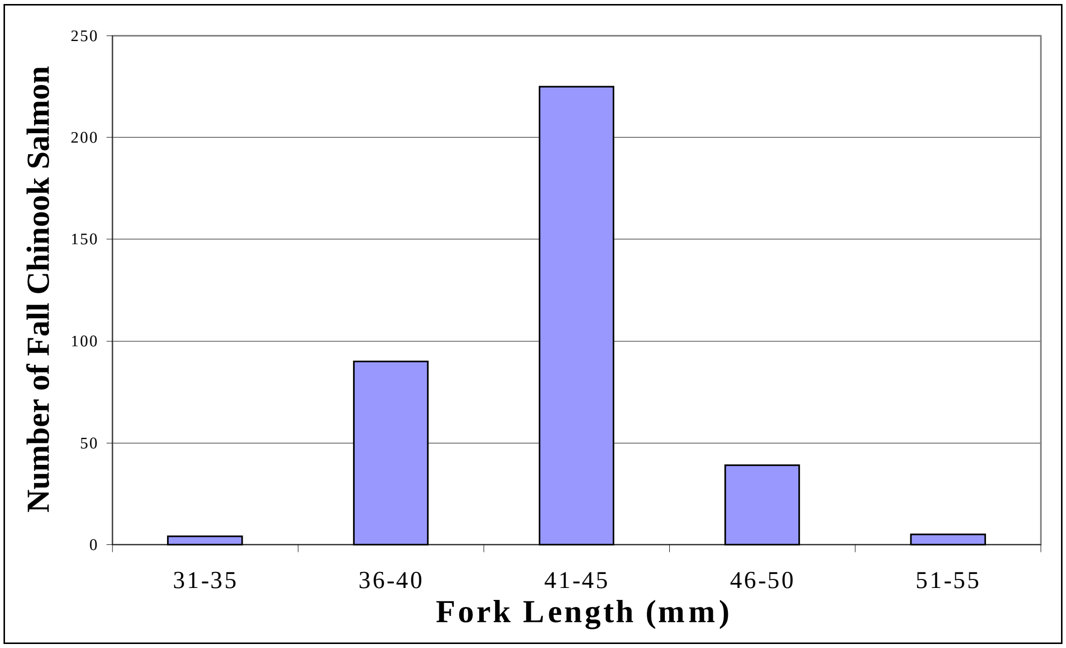

Figure 14. Fork length measurements of juvenile fall chinook salmon collected from random plots on the Hanford Reach of the Columbia River in 2001.

Distribution of Juvenile Fall Chinook Salmon

The portion of the Hanford Reach defined by the SHOALS bathymetry was divided into eight river sections (~5 Rkm in length) and the total amount of shoreline exposed during the entire juvenile fall chinook salmon emergence and rearing period was calculated for each 40 kcfs flow band within each section to determine the horizontal and vertical distribution of stranding and entrapment (**Figure 15**). The total amount of shoreline exposed was calculated by multiplying the amount of shoreline exposed for each flow band at each river section by the number of flow fluctuations that occurred in that flow band over the entire period. The number of flow fluctuations was counted at Rkm 588.3, the closest MASS1 transect to the midpoint of the SHOALS data. Juvenile fall chinook salmon were found throughout the SHOALS defined study area at a variety flow bands but the highest concentrations were found at the island complex area of Locke Island (600-610 Rkm) at flows of 40-80 kcfs.

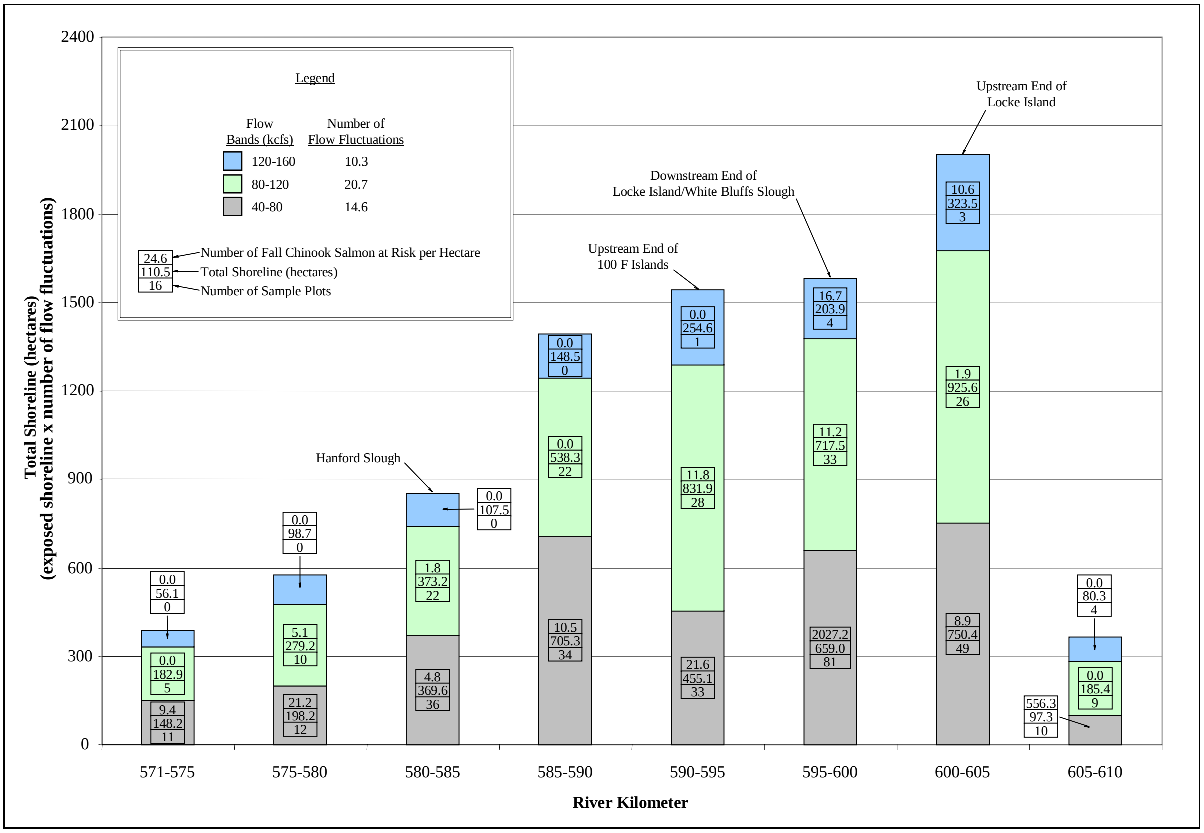

Figure 15. The total area of shoreline exposed during the 2001 juvenile fall chinook salmon emergence and rearing period within 40 kcfs flow band for five kilometer sections of the Hanford Reach of the Columbia River defined by the SHOALS data (Rkm 571.3 to Rkm 606.9). Included in the figure is the number of random plots sampled and the number juvenile fall chinook salmon found per hectare.

Fall Chinook Salmon Fry Production Estimate

To calculate a quantitative impact (% mortality) from losses due to stranding and entrapment from flow fluctuations, fry production for the Hanford Reach needs to be estimated. Fry estimates vary greatly depending on the data used, Priest Rapids Hatchery, PNNL aerial redd counts, fecundity data, sport fishery harvest, carcass recovery, etc. Research has not been conducted to date to determine egg to fry survival rates for fall chinook in the Hanford Reach and this rate may well be variable from year to year. M. C. Healy (1991) reported that under natural conditions, 30% or less of the potential eggs deposited result in emergent fry or fry and fingerling migrants though other studies have reported egg to fry survival as high as 97%. For purposes of estimating a relative impact, an egg to fry survival rate of 30% will be used in this report.

Based on data from Priest Rapids Hatchery, carcass and creel surveys in the Hanford Reach, WDFW escapement estimates, and egg to fry survival rate of 30%, an estimated 27,979,577 fall chinook salmon fry were produced in the Hanford Reach in 2001 (**Table 6**). The Hanford Reach fall chinook salmon escapement estimate for 2000 was 36,027 adults and 11,933 jacks, 47,960 in total (Watson. 2001). Jacks were removed from the calculation as jacks are typically male and do not contribute to egg production. Calculations for female composition of the 2000 escapement were based on sport harvest data indicating 54% (590 of 1,089) of fall chinook salmon harvested on the Hanford Reach were female (**Appendix E**). This estimate assumes that there was an equal chance of harvesting a male or a female, and that there is no gender associated behavioral characteristics which would bias catch. Average fecundity rate for fall chinook salmon at Priest Rapids Hatchery in 2000 was 4,794 eggs per female (Carlson 2001). Egg retention of natural spawners on the Hanford Reach is typically near zero as was the case in 2000 (Watson 2001). This method of estimation may need to be addressed in the future to better refine fry estimates for the Hanford Reach.

Table 6. Calculation of fall chinook fry production for the Hanford Reach, 2001 emergence.

		Literature Cited
2000 Adult Escapement	36,027	Hanford Reach Carcass Survey,Watson 2001
Female (%)	54%	Hanford Reach Sport Fishery, Watson 2001
Fecundity	4,794	Priest Rapids Hatchery, Carlson 2001
# of spawning females	19,455	
Potential eggs	93,265,257	
Egg retention	0	Hanford Reach Carcass Survey, Watson 2001
Total eggs deposited	93,265,257	
Estimated survival (egg to fry)	30%	M.C. Healy, Pacific Salmon Life Histories
Estimated Fry at Emergence	**27,979,577**	

Assessment of Juvenile Fall Chinook Salmon Relative Abundance and Fish Size

Sampling to assess juvenile fall chinook salmon abundance and fish size began on March 14, two weeks prior to the estimated start of emergence on April 1 and ended on June 27 (**Figure 16**). A total of 37,036 juvenile fall chinook salmon were seined during this period. Index sampling was conducted weekly. Peak abundance was observed from April 18 to May 23. The largest catch of the season was obtained on May 9 when 7,262 individuals were sampled.

Newly emergent fall chinook salmon collected on the Hanford Reach often possess ventral slits (unbuttoned), a physical characteristic of the late stage of yolk sac absorption. Fork lengths of these unbuttoned fall chinook salmon ranged up to 44 mm but were most often at or below 42 mm. Juvenile fall chinook salmon with fork lengths at or below 42 mm made up a minimum of 25% of the fish seined in the Hanford Reach through May 23 and fish of this size remained in the samples until June 27. Juvenile fall chinook salmon with fork lengths greater than 59 mm, the size threshold that individuals are thought to become less susceptible to entrapment (Nugent et al. 2001), began to appear in the samples on April 11 but were not collected in considerable numbers (>5%) until June 13. Priest Rapids Hatchery released 6.9 million subyearling chinook salmon from June 11 to June 19 which may have caused an increase in size of fish collected on the Hanford Reach at that time.

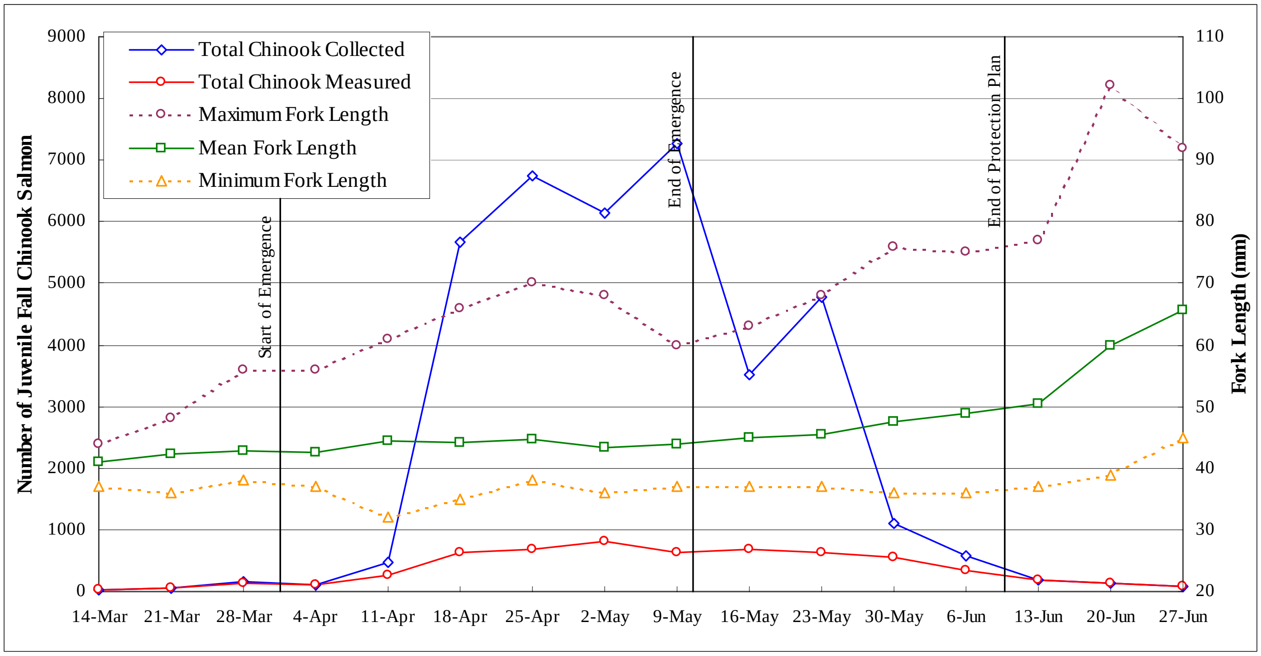

Figure 16. Relative abundance and fork length measurements of juvenile fall chinook salmon collected from nearshore sites on the Hanford Reach of the Columbia River in 2001.

Evaluation of Potential Mortality Events in Primary Fall Chinook Salmon Rearing Areas

The Emergency Management Team (EMT) monitored entrapments in primary fall chinook salmon rearing areas from March 26 to June 28. A total of 27,639 juvenile fall chinook salmon were seined from 63 entrapments. Juvenile fall chinook were observed in an additional ten entrapments that were too large too seine. A total of 98 entrapments were monitored in 2001. Many of the same entrapments were sampled on multiple days during this time period (**Table 7**). Field crews recorded 7,927 direct mortalities at the time entrapments were sampled. Projected mortalities were estimated at 428 based on drainage or lethal temperatures monitored in entrapments. In addition to fall chinook, thousands of resident fish were reported entrapped (**Appendix F**). Criteria for emergency action were reached on five days (May 8, May 9, May 11, May 12, and May 23) in 2001. On May 8, 9, 11, and 12, the combination of water temperatures/drainage rates in entrapment areas reached criteria for implementation of emergency rewetting but action was not taken because increased flows could not be maintained and would most likely result in the entrapment and stranding of additional fish as flows decreased. Chinook were found stranded/entrapped in the random samples during this same period but the mortality rates were not elevated above those of previous weeks. With the combination of warmer weather and the reduction in discharge at Upper Columbia River hydroelectric projects for refilling of Grand Coulee during this period, it was anticipated that some losses would occur. Water temperatures and drainage rates reached criteria for implementation of emergency rewetting on May 23 but random sampling did not indicate large widespread increased mortality.

There were no chinook were found in any of the entrapment areas the week of June 4 through 10. However, during fish rescue operations on June 11, a total of four juvenile wild steelhead/trout fry were found in three entrapments in the Reach. This was the first year of the five year study that steelhead/trout fry had been seined in conjunction with sampling activities. Of the four, three fish were in entrapments that drained and one was captured and released to the river. Between June 11 - 17, after termination of the 2001 Protection Plan, a total of 249 chinook were found in eight entrapments. Of the entrapments monitored, six locations reached lethal or near lethal water temperature. Only one chinook was found in the seven entrapments monitored between June 18 and 24. Of the 7 entrapments monitored, one location reached lethal water temperature and one location was likely to drain. During the last week of EMT sampling, June 25-July 1, chinook were only found in one entrapment area and it was too large to recover fish.

Fish were removed from as many entrapment areas as possible during EMT and random sampling activities. During days in which no fluctuation in discharges from Priest Rapids Dam occurred, sampling crews conducted fish rescue from entrapment areas throughout the Reach. A total of 2,659 fish were seined and returned to the river from March 26 through June 28 during fish rescue. These fish consisted primarily of northern pikeminnow (2,280) and additionally included 171 fall chinook fry, 130 redside shiners, 56 stickleback, 7 suckers, 4 sculpins, 4 steelhead/trout fry, 2 dace, 2 peamouth, 2 smallmouth bass, and 1 crappie.

Table 7. Weekly numbers of juvenile fall chinook salmon found by emergency management teams in primary rearing areas on the Hanford Reach of the Columbia River in 2001.

Week	Number of Entrapments	Total # of Chinook	Chinook Mortalities at Time of Sampling
March- April 1	5	106[1]	4
April 2 - 8	5	1,626[1]	0
April 9 - 15	6	227	6
April 16 - 22	6	643[1]	0
April 23 - 29	5	5,801[1]	1,263[1]
April 30 – May 6	4	4,034	0
May 7 - 13	10	13,672	6,273
May 14 - 20	10	1,651[1]	11
May 21 - 27	8	549	366
May 28 – June 3	6	80[1]	0
June 4 - 10	0	0	0
June 11 - 17	9	249	4
June 18 - 24	7	1	0
June 25 – July 1	17	0	0
Totals	98	28,639[1]	7,927[1]

[1] Total includes entrapments that were too large to seine, numbers of chinook were estimated or not included.

Conclusions

Juvenile Fall Chinook Salmon

Upon emergence, juvenile fall chinook salmon swim or are displaced downstream (Healey 1998) and move to the margins of the river in areas of reduced current velocity (Dauble et al. 1989). From the time of emergence until they are approximately 60 mm in fork length, juvenile fall chinook salmon are subject to flow fluctuations from Priest Rapids Dam. Consequently, fry are forced to move with the shifting shoreline and are found stranded and entrapped in a range of habitat types, flow bands, and river sections. However, some habitat types, flow bands, and river sections are more susceptible to stranding and entrapment of juvenile fall chinook than others. Juvenile fall chinook salmon were found throughout the SHOALS defined study area at a variety of flow bands but the highest concentrations were found at the island complex areas of Locke Island (600-610 Rkm) at flows of 40-80 kcfs. These island complex areas with their large and varied shorelines and diverse shallow water areas appear to provide excellent rearing habitat as well as high stranding and entrapment potential. Large flats or flood terraces are present in these areas at those flow levels. Flood terraces may also be a concern at other river sections and at other flow levels.

Juvenile fall chinook were susceptible to stranding/entrapment from March 14, the date that fish were first found in index samples, through the end of index sampling on June 27. Based on chinook "at risk" in random samples and population abundance from index sampling, the primary period when operations at Priest Rapids Dam appear to have significant impacts on the juvenile fall chinook population was from April 11 through May 30. Criteria established in for the start and ending dates fit closely to susceptibility determined by the evaluation. Data from 1999, 2000, and 2001 all indicate some decrease in susceptibility beginning at roughly 200 temperature units Celsius after the estimated end of emergence, which was May 27 in 2001. This trend was observed in chinook "at risk" and in the length frequency data for all three years. In 2001, the number of chinook at risk decreased dramatically after May 28, even though daily fluctuations in discharge from Priest Rapids were relatively high with a mean daily fluctuation of 83.2 kcfs, May 29-June 28 (**Table 4**). Length frequency data for 2001 show an increase in mean fork length and decrease in abundance at this time (**Figure 16**). The decrease in abundance is most likely due to the movement of larger fish away from near shore areas and/or increased swimming ability resulting in avoidance of capture. Mean weekly fork length increased only 2mm between May 23 and May 30 but the percent of chinook 50mm or larger doubled between these dates (15.7% to 32.6%). The number of newly emerged fry also dropped below 20% of the index collection (19.6%).

The number of dead juvenile fall chinook salmon identified in 2001 is more than 20 times the number estimated for 2000 (72,362) and almost 8 times the revised number of mortalities based on site revisitation in 2000 (Chris Murray, PNNL, **Appendix D**). The major factor that is responsible for the increase from 2000 to 2001 is a very high estimated mean number of mortalities per plot for the 40-80 kcfs flow band. This flow band, which was only incompletely sampled in previous years, was impacted by fluctuations this year because of the lower water levels in the river. The flow band appears to have a higher susceptibility to stranding and mortality of juvenile fall chinook salmon. There was one sample taken in 2001 in that flow band which contained 2,016 juvenile fall chinook mortalities (2,344 on a per plot basis). This one sample greatly increased the mean mortality per plot of that flow band. The mean for 2001 for that flow band was 15.7 mortalities per plot, where most flow bands in previous years have had means of less than 1. However, even if that sample were eliminated, there were several other samples with large numbers of mortalities in that flow band, so that the estimated mean for the 40-80 kcfs flow band for 2001 would be 6.9 mortalities per plot, which would still be much larger than the averages for other flow bands found in 1999 and 2000.

Recommendations

Based on the data from the 1999, 2000, and 2001 evaluations, the current start and end dates for the protection plan as developed for 2001 coincides well with fall chinook emergence and susceptibility. These criteria should continue to be used for establishment of the start and end dates of the protection plan.

Monitoring, including indexing for chinook emergence, abundance, length frequency distribution, and susceptibility to stranding/entrapment should continue to be incorporated into the annual protection plans to ensure protection criteria are meeting the objectives of the plan and coincide with Hanford Reach juvenile fall chinook emergence and rearing.

The magnitude of flow fluctuations which will provide protection for juvenile fall chinook emergence and rearing during low, moderate, and high river flows needs to be further refined. The power managers and fish managers will need to continue to work to find a balance between fish survival and power generation.

The joint fish managers, consisting of WDFW, the Columbia River Intertribal Fish Commission, the Tribes of the Columbia River Basin, the Oregon Department of Fish and Wildlife, NMFS, and USFWS, and the power managers, consisting GCPUD, BPA, the United States Bureau of Reclamation, and the Mid-Columbia Public Utility Districts (Chelan and Douglas Counties), should continue to work together through the Hanford Policy Group meetings to refine annual interim protection plans to protect emergent and rearing juvenile fall chinook in the Hanford Reach area of the Columbia River until a permanent agreement can be adopted. A permanent agreement will need to allow adaptive management options for fish management and hydropower as conditions change.

References

Bauersfeld, K. 1978. Stranding of juvenile salmon by flow reductions at Mayfield Dam on the Cowlitz River, 1976. Technical Report No. 36. Washington Department of Fisheries.

Barfoot, C.A., D. M Gadomski, and R. H. Wertheimer. 1999. Growth and mortality of age-0 northern squawfish, *Ptychocheilus oregonensis*, rearing in shoreline habitats of a Columbia River reservoir. Environmental Biology of Fishes 54:107-115.

Beck, R. W. 1989. Skagit River salmon and steelhead fry stranding studies. Prepared by R. W. Beck Associates for the Seattle City Light, Environmental Affairs Division, Seattle, Washington.

Becker, C. D., D. H. Fickeisen, and J. C. Montgomery. 1981. Assessment of impacts from water level fluctuations on fish in the Hanford Reach, Columbia River. PNL-3813. Pacific Northwest Laboratory. Richland, Washington.

Carlson, C. 2001. Draft Vernita Bar monitoring for 2000-2001. Public Utility District of Grant County. Annual Report.

Dauble, D. D., T. L. Page, and R. W. Hanf, Jr. 1989. Spatial distribution of juvenile salmonids in the Hanford Reach, Columbia River. Fishery Bulletin 87(4):775-790.

Dauble, D. D. Annual chinook salmon redd counts, 1991, 1994, 1995. Battelle Pacific Northwest Laboratory, Richland, Washington.

Dauble, D. D., and D. G. Watson. 1997. Status of fall chinook salmon populations in the Mid-Columbia River, 1948-1992. North American Journal of Fisheries Management 17(2):283-300.

DeVore, J. 1988. Evidence of stranding of zero-age wild fall chinook on the Hanford Reach of the Columbia River. Memorandum to Don McIsaac date June 9, 1988. Washington Department of Fisheries.

Geist, D. 1989. Stranding of zero-age wild fall chinook on the Hanford Reach of the Columbia River. Memorandum to Phil Peterson dated August 7, 1989. Washington Department of Fisheries.

Glantz, C. S., M. N. Schwartz, K. W. Burk, R. B. Kasper, M. W. Ligotke, and P. J. Perrault. 1990 Climatological summary of wind and temperature data for the Hanford meteorology monitoring network. PNL-7471. Pacific Northwest Laboratory, Richland, Washington.

Hanford Meteorological Station. 1999. http://etd.pnl.gov:2080/HMS. Access date September 4, 2000.

Healey, M. C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. Fish. Bull. (U.S.) 77:653-668.

Healey, M. C. 1998. Life history of chinook. In Pacific salmon life histories. C. Groot and L. Margolis, eds. pp. 311-394. UBC Press, Vancouver, British Columbia.

Huntington, C. S., W. Nehlsen, and J. Bowers. 1996. A Survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries 21(3):6-14.

Key, L. O., J. A. Jackson, C. R. Sprague, and E. E. Kofoot. 1994. Nearshore habitat use by subyearling chinook salmon in the Columbia and Snake rivers. In Identification of the spawning, rearing and migratory requirements of fall chinook salmon in the Columbia River Basin. D. W. Rondorf and W. H. Miller, eds. pp. 120-150. Annual Report to Bonneville Power Administration, Contract DE-AI7991BP21708, Portland, Oregon.

Lister, D. B., C. E. Walker, and M. A. Giles. 1971. Cowichan River chinook salmonescapements and juvenile production 1965-1967. Fish. Serv. (Can.) Pac. Reg. Tech. Rep. 1971-3:8 p.

Mason, W. T., Jr., and P. P. Yevich. 1967. The use of phloxine B and rose bengal stains to facilitate sorting benthic samples. Transactions of the American Microscopic Society 86(2):221-223.

Nugent, J., T. Newsome, M. Nugent, W. Brock, P. Wagner, and L. Key. 2001. 1998 Evaluation of juvenile fall chinook salmon stranding on the Hanford Reach of the Columbia River. Prepared for The Bonneville Power Administration and the Public Utility District Number 2 of Grant County. BPA Contract Number 97BI30417 and GCPUD Contracts Document 430-647.

Ocker, P. A. 1996. Observations of salmonid strandings in the Hanford Reach. Memorandum to Paul Wagner dated September 17, 1996. U.S. Fish and Wildlife Service.

Page, T. L. 1976. Observations on juvenile salmon stranding in the Columbia River, April 1976. Report of Battelle Pacific Northwest Laboratories to United Engineers and Contractors for Washington Public Water Supply System, Richland, Washington.

Phinney, L. A. 1974a. Further observations on juvenile salmon stranding in the Skagit River, March 1973. Washington Department of Fisheries.

Phinney, L. A. 1974b. Report on the 1972 study of the effect of river flow fluctuations below Merwin Dam on downstream migrant salmon. Washington Department of Fisheries.

Platts, W. S., W. F. Megaham, and H. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Forest Service, General Technical Report INT-138, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Rickard, W. H. 1988. Climate of the Hanford Site. In Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem. Developments in agricultural and managed-forest ecology 20. W. H. Rickard, L. E. Rogers, B.E. Vaughan, and S. F.Liebetrau, eds. pp. 13-21. Elsevier, New York.

Richmond, M. C. and W .A. Perkins. 1998. Draft MASS1 Modular Aquatic Simulation System 1D A one dimensional hydrodynamic and water quality model for river systems. Pacific Northwest Laboratory, Richland, Washington.

Thompson, J. S. 1970. Skagit River fry mortality study, March 1969. Washington Department of Fisheries.

Tipping, J., P. Buckley, and J. Danielson. 1978. Cowlitz River steelhead spawning and fry stranding study, 1977-78. Progress Report. Washington Department of Game.

Tipping, J., S. Springer, P. Buckley, and J. Danielson. 1979. Cowlitz River steelhead spawning, fry emergence and stranding, 1977-79, and adult life history study, 1977-79. Washington Department of Game.

United States Geological Survey Gauging Station # 12472800 Below Priest Rapids Dam 1987-1998. http://www.cqs.washington.edu/dart/headwater_calm.html. Access Date July 25, 2000.

Wagner, P. G. 1995. May 14, 1995 Observations of trapped and stranded fall chinook fry near the Vernita Bridge. Memorandum to W. Dammers dated May 16, 1995. Washington Department of Fish and Wildlife.

Wagner, P., J. Nugent, W. Price, R. Tudor, and P. Hoffarth. 1999. 1997-99 Evaluation of juvenile fall chinook stranding on the Hanford Reach. 1997 Interim Report. Prepared for The Bonneville Power Administration and the Public Utility District Number 2 of Grant County. BPA Contract Number 97BI30417 and GCPUD Contracts Document 430-647.

Wales, J. H., and M. Coots. 1954. Efficiency of chinook salmon spawning in Fall Creek, California. Trans. Am. Fish. Soc. 84:137-149.

Watson, R. 2001. 2000 Hanford Reach fall chinook stream survey summary. Pacific States Marine Fisheries Commission.

White, R. G., A. E. Bingham, J. H. Milligan, M. A. Brusven, and C. A. Corraino. 1985. Effects of reduced stream discharge on fish and aquatic macroinvertebrate populations phase II. Research Technical Completion Report. Idaho Water Resources Research Institute, University of Idaho, Moscow.

Witty, K. and K. Thompson. 1974. Fish stranding surveys. In: Anatomy of a river. K. Bayha and C. Koski eds. pp. 113-120. Pacific Northwest River Basins Commission, Vancouver, Washington.

Woodin, R. 1984. Evaluation of salmon fry stranding induced by fluctuating hydroelectric discharge in the Skagit River, 1980-83. Technical Report No. 83. Washington Department of Fisheries.

Appendix A

2001 Hanford Reach Juvenile Fall Chinook Protection Program

2001 Hanford Reach Juvenile Fall Chinook Protection Program
March 2, 2001

The criteria for development of this program as proposed by the mid-Columbia hydroelectric operators are:

1. Provide a high level of protection for rearing fall chinook fry;
2. Maintain reasonable load following capability at all 7 projects;
3. Monitoring and evaluation that allows evaluation of the program relative to its effect on entrapment and stranding; and
4. A monitoring program that allows in-season changes of operations if substantial mortality is detected.

2001 Program Elements

<u>Starting Program Operating Constraints</u>

1. Begin index seining (6 standard beach seine hauls at pre-determined locations) one week prior to the calculated start of emergence under the Vernita Bar Agreement. Index seining will be conducted daily to define the beginning of susceptibility.

2. Start operational constraints for 2001 program when a daily total of 50 or more sub-yearling chinook is sampled from the 6 index seining stations. During each index seining sample, sub-yearling fork length will be reported. After program is initiated, decrease index seining to one time per week.

<u>**When PRD average weekly discharge is *less than or equal to* 170 kcfs:**</u>

1. If possible, within the requirements of flood control, power generation, project operating constraints, and the BO, a goal of the program will be to incorporate the objective of releasing GCL weekly average discharge in a constant or steadily increasing manner.

2. During the first week of program implementation, the mid-Columbia projects [2] will limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs (difference between daily maximum and minimum).

3. During the following 4 weeks of program implementation, the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 40kcfs.

4. During the sixth week of program implementation, the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs.

[2] The term "mid-Columbia projects", wherever used, includes Priest Rapids, Wanapum, Rock Island, Rocky Reach, Wells, Chief Joseph, and Grand Coulee dams operated under the hourly coordination agreement.

5. Following the sixth week of the program, the WDFW will report the results of random site monitoring for the first six weeks of the program. If the 85% upper confidence limit for the total impact at week six is less than the average of the estimated total impact after six weeks in 1999 and 2000, then the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 80 kcfs for the seventh and eighth weeks of the program. The 85% upper confidence limit for the total impact at week six for 2001 will be calculated as the estimate of cumulative fish at risk through the first six weeks plus 1.036 times the standard error of the estimate. If the 85% upper confidence limit for the total impact at six weeks is greater than the impact trigger, then the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs for the seventh and eighth weeks of the program. If the total impact at six weeks cannot be calculated prior to the start of the seventh week, then the comparison will be made based on the average fish at risk per plot. If the 85% upper confidence limit of the average number of fish at risk per 3,600 ft^2 (a standard full sample plot) is less than or equal to 1.0 (the mean of the week six averages for 1999 and 2000), the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 80 kcfs for the seventh and eighth weeks of the program. The 85% upper confidence limit for the average will be calculated as the average fish at risk per plot plus 1.036 times the standard error of the estimate. If the 85% upper confidence limit for the average number of fish per sample is greater than 1.0, the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs for the seventh and eighth weeks of the program.

6. From the ninth week of the program until the end of program operating constraints, the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 80 kcfs.

When PRD average weekly discharge is *greater* than 170 kcfs:

1. When average weekly discharge at Priest Rapids is greater than 170 kcfs, the mid-Columbia projects will maintain a 150 kcfs minimum hourly discharge at Priest Rapids.

Ending Program Operating Constraints

1. When 400 or more temperature units (°C) have accumulated following the end of emergence under the Vernita Bar Agreement, the operating constraints identified above will end.

2. Monitoring will continue until June 30, 2001 as identified below.

Monitoring, Evaluation and Adaptive Management

1. Monitoring under the program in 2001 will consist of random sampling by 2 full-time crews on a 7 day a week basis within a 17-mile section of the Hanford Reach to determine the overall impact of the program on juvenile fall chinook mortality. A 3rd crew will monitor index sites identified in 1999 and will also contribute to random

sampling. This effort will be led by the WDFW and coordinated with Grant PUD. WDFW will deliver a summary of the previous Monday through Sunday sampling effort to Grant PUD no later than 5:00 pm on Monday.

2. Until stranding susceptibility ends, a weekly report for the Monday through Sunday time period will be produced by Grant County PUD and the WDFW. This report will be available on the Technical Management Team (TMT) website at the following URL:
< www.nwd-wc.usace.army.mil/cgi-bin/proposal.cgi?type=index>
and will be presented at the weekly TMT meetings. This report will also be distributed to the Hanford Reach Stranding Policy Group each Tuesday morning by e-mail. The TMT will serve as a forum for information exchange and will not be involved in decision making under this Program. It is anticipated that TMT decisions will facilitate and support activities under this Program. The authority for implementing any changes under this Program rests with the mid-Columbia projects and any disputes will be handled through meetings of the Hanford Reach Stranding Policy Group.

   A. The weekly report will include the following operational information for each day: minimum hourly discharge from Priest Rapids Dam (PRD), maximum hourly discharge from PRD and day average discharge at PRD. The report will also provide weekly average discharge at PRD.

   B. The weekly reports will also include the following field monitoring information for each day: number of samples taken, number of stranded or entrapped chinook fry and number of chinook mortalities. The weekly report will also include the number of chinook fry sampled from standard index sites which will be used to determine when susceptibility to stranding and entrapment ends.

3. If high levels of chinook entrapment likely to result in mortality are observed, the mid-Columbia operators will evaluate whether to implement operational changes to reduce the level of mortality. At the weekly TMT meeting, the mid-Columbia operators will explain the problem and propose operational changes to resolve it. If there are no significant objections from the Hanford Reach Stranding Policy Group, the operator's proposal will be implemented as soon as practicable.

4. If high levels of chinook entrapment likely to result in mortality are observed and there is significant objection to the mid-Columbia operators' proposal to resolve the problem, the Hanford Reach Stranding Policy Group will meet or hold a conference call within 3 days to resolve the conflict.

5. If the field monitoring crew observe that a significant fall chinook mortality event is occurring or imminent, they will immediately notify the designated representative of the Washington Department of Fish and Wildlife (WDFW) and explain the situation. The WDFW representative will confirm whether a significant fall chinook mortality event is occurring or imminent and decide whether to request a modification of operations. If alteration of operations appears appropriate, the WDFW representative will notify Grant County PUD immediately to discuss a remedy. If Grant County PUD concurs that a

significant fall chinook mortality event is occurring or imminent, it will consult, as necessary, with other operators and an operational remedy will be implemented expeditiously.[3]

6. An e-mail explaining the event and describing the remedy taken will be sent to the Hanford Reach Stranding Policy Group by Grant County PUD no later than the next business day following the event.

[3] It is anticipated that the parties involved will implement this process in no more than a few hours from initial notification to implementation of remedy, day or night.

Appendix B

Substrate Size, Substrate Embeddedness, and Vegetation Codes

Substrate Codes

Dominant substrate is most common to the sample area and subdominant is the next most common substrate class.

Code	Substrate class
1	Fines (clay to coarse sand (<1 mm))
2	Very coarse sand (1-2 mm)
3	Fine gravel (2-4 mm)
4	Medium gravel (4-8 mm)
5	Coarse gravel (8-16 mm)
6	Small pebble (16-32 mm)
7	Large pebble (32-64 mm)
8	Cobble or rubble (64-256 mm)
9	Boulder (>256 mm)

Substrate Embeddedness Codes

The substrate embeddedness is estimated visually. Substrate embeddedness refers to the degree that the interstices between the larger particles are filled by sand, silt or clay.

Code	% Fines	Description
1	0-25	Openings between dominant sized particles are 1/3 to 1/2 the size of the particles. Few fines in between. Edges are clearly discernable.
2	25-50	Openings are apparent but <1/4 the size of the particles. Edges are discernable but up to half obscured.
3	50-75	Openings are completely filled but half of edges are still discernable.
4	75-100	All openings are obscured. Only one or two edges discernable and size cannot be determined without removal.

Vegetation Codes

Vegetation is assessed visually to estimate the percent of ground coverage.

Code	Description
1	No vegetation present.
2	Sparse vegetation, substrate is completely evident.
3	Medium vegetation, substrate is only partially obscured.
4	Dense vegetation, substrate is nearly or completely obscured by the vegetation.

Appendix C

Estimation of Total Number of Juvenile Fall Chinook Salmon At Risk Due to River Flow Fluctuations – First 5 Weeks of 2001 Field Season

Estimation of Total Number of Juvenile Fall Chinook Salmon At Risk Due to River Flow Fluctuations – First 5 Weeks of 2001 Field Season

Pursuant to the 2001 Hanford Reach Juvenile Fall Chinook Protection Program, a comparison was made between the number of juvenile fall chinook at risk due to stranding/entrapment at the end of the first 5 weeks of 2001 and the average of the estimated chinook at risk for the same periods of 2000 and 1999. The purpose of the comparison was to determine the range of flow fluctuations allowed during the seventh and eighth weeks of the Protection Program. The relevant section of the program is included below:

Following the sixth week of the program, the WDFW will report the results of random site monitoring for the first six weeks of the program. If the 85% upper confidence limit for the total impact at week six is less than the average of the estimated total impact after six weeks in 1999 and 2000, then the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 80 kcfs for the seventh and eighth weeks of the program. The 85% upper confidence limit for the total impact at week six for 2001 will be calculated as the estimate of cumulative fish at risk through the first six weeks plus 1.036 times the standard error of the estimate. If the 85% upper confidence limit for the total impact at six weeks is greater than the impact trigger, then the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs for the seventh and eighth weeks of the program. If the total impact at six weeks cannot be calculated prior to the start of the seventh week, then the comparison will be made based on the average fish at risk per plot. If the 85% upper confidence limit of the average number of fish at risk per 3,600 ft^2 (a standard full sample plot) is less than or equal to 1.0 (the mean of the week six averages for 1999 and 2000), the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 80 kcfs for the seventh and eighth weeks of the program. The 85% upper confidence limit for the average will be calculated as the average fish at risk per plot plus 1.036 times the standard error of the estimate. If the 85% upper confidence limit for the average number of fish per sample is greater than 1.0, the mid-Columbia projects will limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs for the seventh and eighth weeks of the program.

After discussion with Grant County Public Utility District, the test was modified to compare data from the first 5 weeks rather than 6 weeks to provide a week to process the data and still provide an estimate prior to the start of the 7^{th} week.

The total number of juvenile fall chinook salmon at risk due to stranding/entrapment was estimated for a portion of the Hanford Reach during the sampling period from March 26 to April 29, 2000. The estimate was based on 70 sample measurements taken in two flow bands of the Hanford Reach: 60-80 and 80-110 thousand cubic feet per second (kcfs). Note that the lowermost and uppermost 40 KCFS bands were truncated because no fluctuations occurred in the range from 40-60 KCFS or in the range from 110-120 KCFS, so their area was truncated to equal the range over which fluctuations occurred. The samples were collected randomly within each flow band within the area in which the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) topographic and bathymetric data was available. As such, the estimate is only representative of a portion of the entire Hanford Reach, and must be considered a minimum estimate. The two flow bands that were sampled in the study area can be considered as two strata, so estimation of the total number of stranded/entrapped juvenile fall chinook salmon was performed using a stratified random sampling algorithm. The algorithm used to develop the total estimate is the same as that reported in 1999 and 2000.

The results of the computation of the number of juvenile fall chinook salmon mortalities due to stranding and those at risk are listed in the table at the end of this memo. The estimate for the total number of juvenile fall chinook salmon at risk within the study area during the period from March 26 – April 29, 2000 is 696,031 (see table below) and an 85% upper confidence interval for that estimate (equal to the estimate plus 1.036 times the standard error) is 1,308,618. Both the 85% upper confidence interval and the total estimate itself are larger than the average of the estimated totals for the same period in 1999 and 2000, which is 105,004.

Due to the low water levels in the river, the number of fluctuations was reduced for the first 5 weeks in 2001, relative to the same periods in 1999 and 2000. This also reduced the number of samples taken during that period (70 in 2001 vs. 320 for the same period in 2000). However, the impact of the fluctuations appears to have been more severe in the first 5 weeks of 2001, as reflected in the larger number of juvenile fall chinook at risk found in those samples. For example, 20% of the samples in 2001 found fish at risk, compared to only 7.5% in 2000. Another factor that influenced the results was a large number of samples that contained high numbers of fish at risk. There was one sample taken in 2001 which contained 2,016 juvenile fall chinook mortalities (2,344 on a per plot basis). This one sample greatly increased the mean and variance of the 2001 data. However, even if that sample were eliminated, there were several other samples with relatively large numbers of fish at risk, so that the estimated total for 2001 would still be larger than the average of the estimated totals for the same period of 1999 and 2000.

The higher estimated total for juvenile fall chinook at risk for 2001 indicates the mid-Columbia projects should limit daily flow fluctuations below Priest Rapids to no more than 60 kcfs for the seventh and eighth weeks of the program, according to the terms of the Protection Program quoted above.

Note that these estimates are all minimum estimates, because the random sampling program only sampled a portion of the Hanford Reach (the portion with SHOALS coverage), and we assume 100% efficiency during the sampling, i.e., that no dead juvenile fall chinook salmon were missed during the sampling of each random plot.

	Year	**Mean, per plot**	**Total**
At risk	1999-2000	1.4	105004
	2001	32.8	696031
Mortalities	1999-2000	0.8	59599
	2001	31.7	672985

Chris Murray
Pacific Northwest National Laboratory
May 3, 2001

Appendix D

Estimation of Total Number of Entrapped and Dead Juvenile Fall Chinook Salmon Due to River Flow Fluctuations - 2001 Field Season

Estimation of Total Number of Dead Chinook Caused by Stranding

Estimation of Total Number of Entrapped and Dead Juvenile Fall Chinook Salmon Due to River Flow Fluctuations - 2001 Field Season

The total number of juvenile fall chinook salmon mortalities due to stranding/entrapment was estimated for a portion of the Hanford Reach during the sampling period from April 12 to June 28, 2001. The start of sampling was delayed in 2001 relative to previous years because no significant fluctuations of river level were observed early in the period of fry emergence. The earliest fluctuations occurred on April 12th, and random sampling started the following day, on April 13th. Because of low water levels in 2001, only three 40 thousand cubic feet per second (kcfs) flow bands of the river were sampled, versus 6 bands in previous years.

The estimate for 2001 was based on 433 sample measurements taken in three flow bands of the Hanford Reach: 40-80, 80-120, and 120-140 kcfs. Note that the uppermost 40 kcfs band was truncated because no fluctuations occurred in the range from 140-160 kcfs, so the area of that flow band was reduced to equal the range over which fluctuations occurred. The samples were collected randomly within each flow band in the area of the Hanford Reach for which Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) topographic and bathymetric data are available. As such, the estimate is only representative of a portion of the entire Hanford Reach, and must be considered a minimum estimate. The three flow bands that were sampled in the study area can be considered as three strata, so estimation of the total number of stranded/entrapped juvenile fall chinook salmon was performed using a stratified random sampling algorithm.

All samples taken during the field season were included in the estimate because the last stranded/entrapped fish was found on June 22nd, less than a week before the end of the random sampling effort on June 28th. The samples used in the estimates for previous years had been truncated so that samples were only included if they were taken within a week after the last stranded/entrapped fish was observed.

A sampling plan was designed by Pacific Northwest National Laboratory (PNNL) and Washington Department of Fish and Wildlife (WDFW) prior to the 2001 field season that identified all potential sampling locations in the study area and determined which flow band they fell in using the SHOALS data and the Modular Aquatic Simulation System 1D (MASS1) flow model. The sample plot size used in the study was approximately 3600 sq ft. Samples were then selected randomly from the population of potential samples within each flow band, with the number of random samples selected being proportional to the size of the flow band. A list of random samples, with location coordinates and the flow band to which they belonged, was provided to the WDFW. Each morning, the target flow band for sampling was identified based on the flow fluctuations in the previous 48 hr period. A list of samples would then be selected from the list of random samples for sampling that day. Each sampling crew would use a high-performance global positioning system (GPS) to navigate to the selected sample locations on the list. An anchor weight was placed at the center of each sample plot, and an incrementally marked wire cable was used to determine the boundary of the circular sampling plot. In many cases, the entire area of the plot could not be sampled, because portions of the plot were still under water at the rivers edge, or were above the wetted shoreline. In those cases, a scaled drawing was made that was later used to estimate the proportion of the plot that could actually be sampled. The number of juvenile fall chinook salmon at risk, dead, or likely to die due to stranding or thermal stress in an entrapment (i.e., due to imminent drainage of the entrapment or high temperature) were counted for each sample plot. Other data were also recorded, including the substrate type, embeddedness, and vegetation density. In 2000 and 2001, an additional step was taken, to revisit entrapments the following day and determine the fate of juvenile fall chinook salmon that had been entrapped.

The first step in the calculation of the total number of dead juvenile fall chinook salmon was to calculate the number of dead juvenile fall chinook salmon per sample plot. If the entire plot could not be sampled, then the number of juvenile fall chinook salmon that would be found in a full size sample plot was estimated by dividing the number of juvenile fall chinook salmon found by the proportion of the area of the plot that was sampled to the standard plot size. The average number of juvenile fall chinook salmon per plot in each flow band, $\bar{x}_h$, was calculated as the sample mean of the number of stranded/entrapped juvenile fall chinook salmon for all samples collected within a flow band h, where samples are denoted as x_{hi}, with $h = 1, 2, 3$ and $i = 1 \ldots n_h$. Here h is the index of the flow band and n_h is the number of samples taken within a flow band h. The equation for estimating the stratified average number of dead juvenile fall chinook salmon per sample plot is:

$$\bar{x}_{st} = \sum_{h=1}^{3} W_h \bar{x}_h \qquad [1]$$

where W_h is the weight of a flow band h. The weights for each flow band are found by calculating the total number of plots in a flow band, N_h, and dividing by the total number of potentially impacted plots in all three flow bands. Note that N_h also accounts for the number of fluctuations of flow over the area of a flow band h, that is, the total number of potentially impacted plots N_h is the number of plots in a flow band h multiplied by the number of fluctuations affecting that flow band (given below). In equation 1, $\bar{x}_h$ is the sample mean of the number of stranded/entrapped juvenile fall chinook salmon per sample plot within a flow band h.

The number of fluctuations occurring during the study period in each of the three flow bands was counted by WDFW personnel using hourly discharge data from Priest Rapids Dam that had been processed using the MASS1 model. The processing was performed to account for attenuation of the amplitude of the fluctuations in river flows as recorded at the project as the flows translate through the Hanford Reach. This attenuation causes a reduction in the number of fluctuations that would be counted at areas downstream of the project. For the estimate, the decision was made to use the number of fluctuations calculated for the middle cross-section in the study area (Transect #85) for the approximate time period covered by the random sampling data (April 12 – June 28, 2001). This is the same procedure followed in 1999 and 2000. The numbers of fluctuations found for each of the three flow bands included in the 2001 estimate (40-80, 80-120, and 120-140 kcfs) are 14.6, 20.7, and 10.3, respectively.

The unbiased estimate of the variance of the stratified average (Var ($\bar{x}_{st}$)) is estimated by the weighted sample variance using Eq.[2]:

$$s^2\left(\bar{x}_{st}\right) = \sum_{h=1}^{3} W_h^2 \frac{s_h^2}{n_h} \qquad [2]$$

where the variance of the number of dead juvenile fall chinook salmon per sample plot for each flow band is calculated by

$$s_h^2 = \frac{1}{n_h}\sum_{i=1}^{n_h}\left(x_{hi} - \bar{x}_h\right)^2 \qquad [3]$$

The total number of dead juvenile fall chinook salmon, $\hat{I}$, over the entire area of the three flow bands is estimated by Eq.[4]:

$$\hat{I} = \sum_{h=1}^{3} N_h \bar{x}_h = N\bar{x}_{st} \qquad [4]$$

The estimate of the variance of $\hat{I}$ is also used to estimate the standard error and was obtained from Eq.[5]:

$$s^2\left(\hat{I}\right) = N^2 s^2\left(\bar{x}_{st}\right) \qquad [5]$$

The 95% confidence interval of the estimated total number of juvenile fall chinook salmon mortalities is determined by Eq.[6]:

$$\hat{I} \pm 1.96 * s\left(\hat{I}\right) \qquad [6]$$

assuming a normal distribution.

The results of the computation of the number of juvenile fall chinook salmon mortalities due to stranding and those at risk are listed in the first table at the end of this memo. For comparison, the results from the 1999 and 2000 field seasons are included in separate tables. The number of Morts given in the first table is the number of dead juvenile fall chinook salmon estimated using the same procedure followed in 1999. The number in the 2000 table denoted Rev Morts indicates the number of dead juvenile fall chinook salmon based on revisiting the sites of randomly sampled entrapments to determine the number of juvenile fall chinook salmon at risk that died over the next 24 hours due to drainage of the entrapment, high temperatures, etc. In 2001, all but one of the juvenile fall chinook salmon entrapment events observed in random samples were immediately classified as mortalities, so the difference between the at risk and dead salmon is much smaller than in previous years. The one sample that was not immediately classified as a mortality event did not lead to mortalities after 24 hours when the site was revisited. This site was never classified as a mortality event, therefore the Mort and Rev Mort estimates for 2001 are identical.

The estimate for the total number of juvenile fall chinook salmon that died within the study area during the period from April 12 – June 28, 2000 is 1,628,878 (see table below) and a 95% confidence interval for that estimate is [-286,153 to 3,543,910]. The number of mortalities estimated by revisiting the site was the same, and the estimated number of juvenile fall chinook salmon at risk was slightly higher, at 1,663,636. The number of dead juvenile fall chinook salmon identified in 2001 is more than 20 times the number estimated for 2000 (72,362) and almost 8 times the revised number of mortalities based on site revisitation in 2000. The major factor that is responsible for the increase from 2000 to 2001 is a very high estimated mean number of mortalities per plot for the 40-80 kcfs flow band. This flow band, which was only incompletely sampled in previous years, was impacted by fluctuations this year because of the lower water levels in the river. The flow band appears to have a higher susceptibility to stranding and mortality of juvenile fall chinook salmon. There was one sample taken in 2001 in that flow band which contained 2,016 juvenile fall chinook mortalities (2,344 on a per plot basis). This one sample greatly increased the mean mortality per plot of that flow band. The mean for 2001 for that flow band was 15.7 mortalities per plot, where most flow bands in previous years have had means of less than 1. However, even if that sample were eliminated, there were several other samples with large numbers of mortalities in that flow band, so that the estimated mean for the 40-80 kcfs flow band for 2001 would be 6.9 mortalities per plot, which would still be much larger than the averages for other flow bands found in 1999 and 2000.

Note that these estimates are all minimum estimates, because the random sampling program only sampled a portion of the Hanford Reach (the portion with SHOALS coverage), and we assume 100% efficiency during the sampling, i.e., that no dead juvenile fall chinook salmon were missed during the sampling of each random plot.

2001 Field Season

	Mean	Mean – 1.96 S.E.	Mean + 1.96 S.E.
Morts	1,628,878	-286,153	3,543,910
At Risk	1,663,636	-252,186	3,579,458

2000 Field Season

	Mean	Mean – 1.96 S.E.	Mean + 1.96 S.E.
Morts	72,362	34,270	110,454
Rev Morts	209,997	-20,483	440,476
At Risk	255,222	17,743	492,701

1999 Field Season

	Mean	Mean – 1.96 S.E.	Mean + 1.96 S.E.
Morts	125,695	50,724	200,666
At Risk	381,897	-347	764,141

Chris Murray

Pacific Northwest National Laboratory
August 2001

Appendix E

Data used in Hanford Reach Fall Chinook Salmon Fry Production Estimate

2000 Hanford Reach Sport Harvest

Week	Male	Female	Jack	Total Adult	% Female
8/16 - 8/20	0	0	0	0	
8/21 - 8/27	1	3	0	4	75%
8/28 - 9/3	16	26	1	42	62%
9/4 - 9/10	36	48	4	84	57%
9/11 - 9/17	27	31	9	58	53%
9/18 - 9/24	49	41	23	90	46%
9/25 - 10/1	66	99	42	165	60%
10/2 - 10/8	130	127	61	257	49%
10/9 - 10/15	99	111	46	210	53%
10/16 - 10/22	57	79	32	136	58%
10/23 - 10/29	17	25	10	42	60%
10/30 - 11/5	1	0	1	1	0%
Totals	499	590	229	1,089	54%

Published estimates of mortality (%) of chinook to various development stages in fresh water
(mean of ranges in Parentheses)

River system	Eggs not spawned	Losses at spawning	Spawning to eyed stage	Spawning to alevin	Spawning to emergence	Spawning to fry/smolt	Remarks
Mill Cr. (CA)					85-100 (96)		Planted eggs, flooding channel
					40		Planted eggs, controlled flow
Fall Cr. (CA)					68-93 (85)		Natural spawning
Prairie Cr. (CA)		1.0	0-25.5 (10)	14-25 (18)			Natural spawning redd sampling
Yakima (WA)	1.0					84-95 (89)	Stream-type, weir counts of smolts
Lemhi (ID)				27	58		Emergence trap over one redd
Cowichan (BC)						84-91 (87)	Ratio of fry/smolt migrants to eggs
Nanaimo (BC)						80-88 (84)	Ratio of fry/smolt migrants to eggs
Big Qualicum (BC)	12					93-100	Before flow control
						80-88	After flow control
Skeena System							
Bear R. (BC)	25						
Morice R. (BC)	1						
Babine R (BC)	20						
Kamchatka (USSR)	1	88		1-6 (3)			Redd Sampling

Table taken from Groot and Margolis 1998.

Appendix F

Emergency Management Team Entrapments

Date	Start Time	Stop Time	Site	Entrapment	# of CH0	# of Morts	Temp. (°C) Min.	Temp. (°C) Max.	Drain Rate	Notes
3/26/01	10:00	13:59	Hanford Slough	8	47	0	15.7	16.1	2	Large entrapment, not all fish caught
3/26/01	10:00	13:59	Hanford Slough	19	*	0	14.7	16.2	2	* CH0 observed, entrapment too large to seine
3/27/01	9:52	11:30	Locke Island	15	1	1	N/A	N/A	2	Previous entrapment, many resident fish entrapped
3/27/01	9:52	11:30	Locke Island	New	5	3	N/A	N/A	4	Stranding event
3/29/01	11:00	12:00	100 F Islands	17	53	0	14.1	14.1	2	106 resident fish entrapped
4/4/01	11:05	11:45	Hanford Slough	8	*	0	13.1	13.1	2	* CH0 observed, entrapment too large to seine
4/4/01	11:05	11:45	Hanford Slough	19	*	0	10.7	10.7	2	* CH0 observed, entrapment too large to seine
4/5/01	11:00	13:26	100 F Islands	23	208	0	10.2	14.8	1	86 resident fish entrapped
4/6/01	10:56	14:17	Hanford Slough	8	682	0	15.3	-	2	Same Entrapment as 3/26/01 and 4/4/01
4/6/01	10:56	14:17	Hanford Slough	19	736	0	14.2	-	2	Same Entrapment as 3/26/01 and 4/4/01
4/13/01	9:00	12:02	Hanford Slough	19	48	2	7.4	13.6	1	4 resident fish entrapped
4/14/01	9:45	14:40	Locke Island	19	10	1	7.8	11.7	1	Entrapment reflooded
4/14/01	9:45	14:40	Locke Island	20	15	1	10.4	14.7	2	19 resident fish entrapped
4/14/01	9:45	14:40	Locke Island	21	30	1	11.9	12.3	2	1000's resident fish entrapped
4/14/01	9:45	14:40	Locke Island	22	15	1	10.8	11.8	2	1000's resident fish entrapped
4/15/01	8:57	16:48	100 F Islands	24	109	0	13.6	23.6	2	
4/16/01	9:15	14:47	Hanford Slough	8	*	0	11.0	24.4	2	* ~20 CH0 observed, entrapment too large to seine
4/16/01	9:15	14:47	Hanford Slough	19	*	0	11.4	18.9	2	* CH0 observed, entrapment too large to seine
4/17/01	15:00	17:00	Locke Island	23A	270	0	18.1	18.1	2	
4/17/01	15:00	17:00	Locke Island	23B	192	0	18.8	19.1	2	
4/19/01	11:50	14:30	Hanford Slough	8	181	0	19.5	26.1	2	Same entrapment as 4/16/01, CH0 appeared thermally stressed
4/19/01	11:50	14:30	Hanford Slough	19	*	0	15.2	18.4	2	* CH0 observed, same entrapment as 4/16/01, too large to seine
4/24/01	9:49	16:45	100 F Islands	23	453	453	14.2	26.7	2	6 resident fish entrapped
4/24/01	9:49	16:45	100 F Islands	24	2339	0	18.6	27.2	2	281 resident fish entrapped
4/26/01	9:15	14:45	Locke Island	23A&B	~2199	0	18.4	21.4	2	Subsample, ~234 resident fish entrapped
4/26/01	9:15	14:45	Locke Island	25	110	110	N/A	24.7	2	
4/26/01	9:15	14:45	Locke Island	26	~700	~700	N/A	>24.0	2	Crew had to leave for medical emergency
5/2/01	11:45	15:40	Locke Island	27	387	0	18.5	24.9	2	4 resident fish entrapped
5/2/01	11:45	15:40	Locke Island	28	3486	0	20.6	20.6	2	1 resident fish entrapped
5/3/01	10:45	13:30	100 F Islands	23	115	0	15.6	21.7	2	2 resident fish entrapped
5/3/01	10:45	13:30	100 F Islands	25	46	0	20.5	24.6	2	3 resident fish entrapped
5/8/01	10:00	15:00	Locke Island	29	1085	96	18.8	28.8	3	
5/8/01	10:00	15:00	Locke Island	30	106	0	25.8	26.9	2	
5/9/01	8:50	15:45	100 F Islands	23	33	0	15.2	26.2	1	1 resident fish entrapped
5/9/01	8:50	15:45	100 F Islands	24	44	0	18.2	26.8	2	3 resident fish entrapped
5/10/01	9:00	13:30	Hanford Slough	19	6076	0	13.7	22.7	2	1131 resident fish entrapped

5/11/01	10:30	15:56	Locke Island	New	~325	~325	21.5	21.5	4	
5/11/01	10:30	15:56	Locke Island	29	5793	5793	21.3	26.1	2	5790 resident fish entrapped
5/12/01	9:30	15:20	100 F Islands	25	97	58	25.7	30.1	3	2 resident fish entrapped
5/12/01	9:30	15:20	100 F Islands	26	66	0	23.7	30.2	3	
5/12/01	9:30	15:20	100 F Islands	27	47	1	24.7	31.5	3	1 resident fish entrapped
5/14/01	9:30	14:00	Locke Island	31	194	0	12.8	N/A	2	135 resident fish entrapped
5/14/01	9:30	14:00	Locke Island	32	46	5	13.1	N/A	2	1 resident fish entrapped
5/15/01	10:30	13:30	100 F Islands	25	75	0	18.1	21.8	1	4 resident fish entrapped
5/17/01	10:30	14:10	Locke Island	33	58	0	14.1	16.3	1	7 resident fish entrapped
5/17/01	10:30	14:10	Locke Island	26A	189	0	16.3	19.2	1	1 resident fish entrapped
5/19/01	9:10	12:57	Hanford Slough	19	1000's	0	13.9	18.7	2	Entrapment too large to seine, 4 large bass
5/19/01	9:10	12:57	Hanford Slough	20	9	0	18.2	22.4	2	
5/20/01	12:00	15:30	Locke Island	30	69	5	15.8	18.9	2	
5/20/01	12:00	15:30	Locke Island	30B	11	1	18.5	19.7	1	2 resident fish entrapped
5/23/01	9:30	15:00	Locke Island	34	13	0	18.5	32.0	2	
5/23/01	9:30	15:00	Locke Island	35	13	0	18.9	27.6	2	18 resident fish entrapped
5/24/01	10:30	14:00	100 F Islands	25	355	355	20.3	26.9	1	9 resident fish entrapped
5/25/01	9:30	15:14	Hanford Slough	21	6	2	25.4	31.1	1	1 resident fish entrapped
5/26/01	9:30	16:00	Locke Island	36	5	0	21.7	21.7	4	
5/26/01	9:30	16:00	Locke Island	33	64	0	19.1	19.3	1	4 resident fish entrapped
5/26/01	9:30	16:00	Locke Island	37	9	9	30.5	30.5	2	
5/27/01	9:00	14:42	100 F Islands	27	84	0	23.0	27.6	2	1 resident fish entrapped
5/28/01	9:30	14:00	Hanford Slough	19	-	0	18.7	21.2	2	CH0 present, entrapment too large to seine, bass observed
5/30/01	13:00	15:00	100 F Islands	25	~50	0	19.5	19.5	1	
5/31/01	9:11	10:00	Hanford Slough	8	0	0	-	-	2	
5/31/01	9:30	9:45	Locke Island	New	~30	0	19.4	19.4	1	
6/2/01	N/A	N/A	Hanford Slough	19	0	0	0	0	2	large entrapment, not in danger. No ch-0 observed.
6/3/01	N/A	N/A	Locke Island	New	0	0	0	0	2	1 small entrapment with 0 ch-0 and 2 small bass observed.
6/9/01	9:00	9:27	Hanford Slough	-	0	0	-	-	-	Many entrapments, no CH0 observed
6/9/01	-	-	100 F Islands	-	0	0	-	-	-	No CH0 observed
6/10/01	8:30	14:00	Locke Island	-	0	0	-	-	-	Some resident fish entrapped but no CH0 observed
6/12/01	12:00	14:00	Locke Island	22	2	0	13.3	13.3	2	122 resident fish
6/12/01	12:00	14:00	Locke Island	21	2	0	13.6	13.6	2	74 resident fish
6/12/01	12:00	14:00	Locke Island	35	0	0	12.9	12.9	2	20 resident fish
6/13/01	9:00	15:50	100 F Islands	22	2	0	17.2	25.0	2	
6/13/01	9:00	15:50	100 F Islands	17	44	0	18.7	26.1	2	3 resident fish
6/14/01	9:05	16:00	Locke Island	43	75	0	20.6	26.0	2	1 resident fish
6/14/01	9:05	16:00	Locke Island	44	89	0	21.4	25.7	2	2 resident fish

6/14/01	9:05	16:00	Locke Island	20	17	0	-	27.1	2	20 resident fish
6/16/01	10:45	14:10	Locke Island	45	18	4	22.2	28.3	2	
6/17/01	-	-	100 F Islands	-	0	0	-	-	-	Some entrapments, no fish observed
6/18/01	10:00	10:30	Hanford Slough	8	0	0	19.9	19.9	2	3 large bass
6/18/01	10:00	10:30	Hanford Slough	19	0	0	17.1	17.1	2	Entrapment too large to seine, 40-50 large bass
6/19/01	9:30	10:37	Locke Island	6A	0	0	-	-	2	3 juvenile resident fish and other larval fish
6/19/01	9:30	10:37	Locke Island	3	0	0	-	-	2	
6/20/01	9:40	11:43	100 F Islands	13	1	0	20.4	27.4	3	
6/23/01	9:00	15:30	100 F Islands	-	0	0	-	-	-	Many entrapments, no fish observed
6/24/01	9:30	-	Locke Island	-	0	0	-	-	-	Many entrapments, no fish observed
6/26/01	8:50	9:58	Hanford Slough	7	0	0	-	-	2	No fish observed
6/26/01	8:50	9:58	Hanford Slough	8	0	0	-	-	2	No fish observed, still draining to river
6/26/01	8:50	9:58	Hanford Slough	21	0	0	-	-	2	No fish observed
6/27/01	9:00	11:30	Locke Island	22	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	25	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	19	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	20	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	21	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	33	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	34	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	26A & B	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	6A	0	0	-	-	2	
6/27/01	9:00	11:30	Locke Island	45	0	0	-	-	2	Numerous NPMs in entrapment
6/28/01	8:55	10:21	100 F Islands	17	0	0	-	-	2	
6/28/01	8:55	10:21	100 F Islands	25	0	0	-	-	2	
6/28/01	8:55	10:21	100 F Islands	28	-	-	-	-	1	CH0 present, too large to seine