USERS GUIDE TO INSTALLATION OF ARTIFICIAL BURROWS FOR BURROWING OWLS

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19 August 2010

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This Users Guide is sponsored by

Tree Top, Inc., Global Owl Project, and the Wildlife Research Institute

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Suggested Citation: Johnson, D.H., D.C. Gillis, M.A. Gregg, J.L.Rebholz, J.L. Lincer, and J.R. Belthoff. 2010. Users guide to installation of artificial burrows for Burrowing Owls. Tree Top Inc., Selah, Washington. 34 pp. Pdf available from URLs: www.globalowlproject.com, or www.wildlife-research.org

We truly appreciate the support and sponsorship from these organizations:

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National Environmental Education Foundation, 4301 Connecticut Avenue NW, Suite 160, Washington, DC 20008, through the Dept. of Defense Legacy Grants provided funding for the National Public Lands Day, 2010. (202) 833-2933 http://www.neefusa.org/

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Burrowing Owl Conservation Society of British Columbia

EXECUTIVE SUMMARY

Western Burrowing Owl (*Athene cunicularia hypugea*) populations have been declining across nearly all portions of their North American range (Klute *et al.* 2003). Range contraction and fragmentation is a significant concern for this owl. Artificial Burrow Systems (ABS) have been in use since the 1970's, and this management tool has been thoughtfully studied and refined since its inception. In this Users Guide, we provide a synthesis of material relevant to the use of ABS for Burrowing Owls, insights into the placement of ABS, design specifications and installation techniques, and fundamental anti-predator strategies.

ABS should not be designed to simply maintain the species (with the exception of the Imperial Valley of California, the species is not maintaining itself now over most of its range), but rather should meaningfully contribute to slowing the rate of population decline, and directly help in the recovery and conservation of the species. Additionally, burrow systems need to be simple in design, very low-cost, easy to install and maintain, durable, and very efficient. We recognize that this is a lot to ask of artificial burrows. Further, the fundamental underlying issue here is the loss of habitat as well as the persecution and loss of the mammal species (e.g., badger, prairie dog, ground squirrels) which have historically provided the burrows that the owls use. Thus, while ABS are genuinely helpful, they address only part of the real conservation issue occurring in our open grassland, sagebrush and arid-land communities. The use of artificial nest structures is not new to wildlife conservation nor to owls, specifically, as a number of cavity-nesting forest owl species are supported largely by wooden nest boxes in Finland (Saurola 2009). This does not mean that boxes are preferred as a management method over natural sites (they are not), but given other ecosystem management systems, the only operational choice is the use of nest boxes as a conservation safety net for the owls.

In this document we first examine the dimensions of burrows made by the main fossorial mammal species, i.e., American Badger (*Taxidea taxus*), Black-tailed Prairie Dog (*Cynomys ludovicianus*), and various species of large ground squirrels (*Spermophilus* spp.), that provide the burrows used by burrowing owls. We then offer a review of other ABS designs, and follow that with details on an ABS design that reflects the combination of features from other ABS systems, and integrate elements that we have found successful in our work.

We suggest two artificial burrow system (ABS designs): one design employs the use of half of a 208 l (55-gallon) barrel for the nest chamber (i.e., 50 cm, 20 in., in diameter, 1960 cm^2 interior floor space) and two stacked 9.5 l (2.5 gal.) buckets on top for access. The main tunnel is a 2.4 m (10-ft) section of 15 cm (6 in.) diameter corrugated flex drain pipe with a 7.5 cm (3 in.) slot cut out of the bottom to provide a dirt walkway for the owls), and an anti-predator patio. The occupancy rate of this design through the 2010 nesting season (with 59 units in place) on a northeastern Oregon study site has been 86%. Our second design is this same basic concept, except that we use a 10 cm (4-in.) diameter flex pipe main tunnel without a walkway slot, rather than the 15 cm diameter version. As owls have shown a clear preference with sites that have many burrows, a minimum of two (or three) burrow units should be placed at a given site (about 5-10 m apart). We also make recommendations as to selection criteria for placement of the ABS system, and specifics on short perches (i.e., $\leq$60 cm, 24 in.) and related anti-predator aspects.

INTRODUCTION

In general, western burrowing owls (*Athene cunicularia hypugea*) nest in areas of short grasses or other sparse vegetation, but their most basic habitat requirement is a burrow. In an environment with few refuges, nesting in a burrow provides owls protection from many grassland predators, a relatively constant microclimate for nesting and thermoregulation, protection from hazardous or inclement weather such as heavy rain, extreme heat, snow, hail or strong winds, and an area in which to cache prey items. Juvenile burrowing owls depend on burrows during the post-fledging, pre-migratory period, roosting almost exclusively in association with burrows. Even during migration and on the wintering grounds, burrowing owls are found roosting in association with burrows. Any understanding of habitat associations or actions to manage habitat for the benefit of this species must include burrows as a key component (Poulin *et al.* 2005).

The main species that make the burrows for burrowing owls are the badger, prairie dog, and large ground squirrels. The California ground squirrel (*Otospermophilus beecheyi*), is the most common (widespread) burrow provider in California and the round-tailed ground squirrel (*Xerospermophilus tereticaudus*), supplemented by Botta's pocket gopher (*Thomomys bottae*) is the one that provides almost all the burrows for owls in the Imperial Valley, which houses over 70% of California's burrowing owls. The obligate association of burrowing owls with the fossorial (i.e., digging) animals who make the burrows they use, leaves them susceptible to changes in the populations of distributions of these animals. Prairie Dogs have been extirpated from 90% of their former range. Badgers have been persecuted in farmland sites, and their numbers have dropped substantially. Also, in areas where coyote-control programs were instituted, badgers became "by-catch" and the inadvertent impact nearly always resulted in the death of the badgers. Construction in large open areas, has eliminated substantial areas of ground squirrel habitat. The widespread practice of poisoning "vermin" has substantially impacted ground squirrel populations throughout their range. As a consequence of the loss of habitat and burrow-making mammals, the range of the owl is subsequently declining (Fig. 1).

Artificial burrow systems (ABS) for Burrowing Owls have been used since the 1970s (Collins & Landry 1977) to help provide nesting and over-wintering sites, mitigate construction impacts or habitat loss, help to support reintroduction and relocation programs, and as a key research tool to more efficiently monitor population trends and demography. Artificial burrows for burrowing owls are often used as a stop-gap measure, to either provide nest burrows in areas without them, or strategically augment some landscape areas to stabilize and increase the numbers of owl pairs.

For this Users Guide, we examined studies from British Columbia, Alberta, Saskatchewan, Idaho, Oregon, Arizona, California, Oklahoma and Texas involving specific design and placement aspects of artificial burrow systems (ABS) for burrowing owls. The framework for our work was driven by: 1) our desire to highlight the most successful features from existing ABS designs, 2) incorporate a synthesis of results from studies that have tested design aspects of ABS, 3) incorporate the most successful aspects of our own ABS work, 4) compare these design elements against features within natural burrows, and 5) offer a burrow design that builds on all of these components.

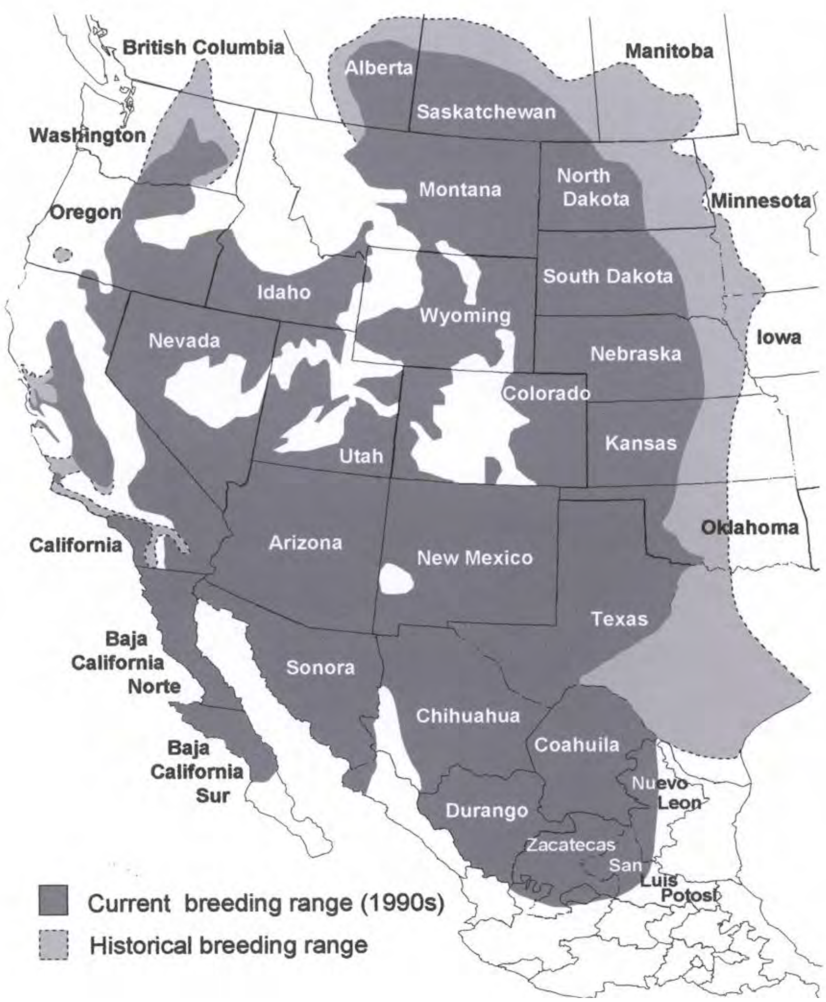


Figure 1. Map of burrowing owl range, and range contraction (after Klute *et al.* 2003).

GOALS FOR THE USE OF ARTIFICIAL BURROW SYSTEMS

The use of ABS is growing, and significant effort will be invested in installing and maintaining them. From a management perspective, it is relevant to have objective and measureable goals against which we can measure/track our ABS investments and successes. ABSs have been used since the 1970's to manage populations of the Western Burrowing Owl (*A.c. hypugaea*), study their breeding biology, and prevent construction impacts or mitigate habitat loss. While the initial goal of ABS for burrowing owls was to minimize construction impacts, we recognize that the goals have broadened given the shift to a more multi-national conservation- and recovery-minded perspective. We offer the following revised ABS goals:

1) as a strategic, broad-scale, conservation tool to slow the rate of population decline,
2) support local and regional reintroduction and augmentation efforts,
3) provide a basis for scientific studies and the efficient monitoring of population trends and demography,
4) use in specific relocation efforts related to construction activities, and
5) use as a practical educational and engagement tool.

BURROW DIMENSIONS FROM THE NATURAL BURROW MAKERS

Figure 2. The main mammal species that create the burrows used by Burrowing Owls. Clockwise from upper left: Black-tailed Prairie Dog (*Cynomys ludovicianus*), a number of ground squirrel species (Richardson's Ground Squirrel *Spermophilus richardsonii* shown here), and American Badger).

Burrowing owls typically live in loose colonies, using burrows excavated by other animal species for cover. When selecting a burrow, the owls prefer burrows with low, open cover that provide good horizontal visibility. Burrowing owls are commonly found in plant communities in early stages of succession because cover is low. Long-abandoned burrows are usually not used because the burrow entrance has become overgrown. Burrows adjacent to burrows occupied by other burrowing owls are preferred, although burrowing owl pairs have nested alone if other burrowing owls were not in the area.

We have examined seven papers that offer specific dimensions on the height, width, and/or length of burrow tunnels used by burrowing owls (Table 1). The seven natural burrows (apparently old badger burrows) used by nesting owls we have examined in northeastern Oregon were from 2.4-5.0 m in length (D.H. Johnson unpubl. data). A good summary statement about the size of burrow tunnels used for nesting by the owls in Saskatchewan was found in Poulin *et al.* (2005): *Burrowing owls preferentially select nest sites in grassland pastures and avoid nesting in crop fields. They choose to nest in burrows surrounded by a high density of other burrows and that tend to resemble badger burrows, having larger soil mounds and taller entrances than random or Richardson's Ground Squirrel (*Spermophilus richardsonii*) burrows. Owls chose nest burrows with an entrance height of 15-16 cm, an entrance smaller than the average badger burrow (18-19 cm) but larger than the average ground squirrel burrow (9-10 cm).* Similar results have been found in other parts of the U.S (Table 1).

Table 1. Dimensions of natural burrows used by burrowing owls for nesting. Except for the Butts & Lewis (1982) reference, all dimensions are the averages stated in the papers and are given in cm.

Study location	**species**	**n**	**dia.**	**ht**	**width**	**length**	**source**
New Mexico	Rock Squirrel (*Spermophilus variegates*)	15 owl nests		11 cm	20 cm		Martin 1973
Imperial Valley, CA		104 owl nests	20 cm				Coulombe 1971
South Dakota	Prairie Dog	180 owl nests	13 cm				MacCracken *et al.* 1985
Idaho		32 owl nests		14.8 cm	20.2 cm		Belthoff & King 2002
Saskatchewan		22 owl nests		15.4 cm			Poulin *et al.* 2005
Oklahoma	Prairie Dog	11 owl nests		11-13 cm	14-15 cm	150 cm	Butts & Lewis 1982
Oklahoma	Badger	2 owl nests		15cm & 19 cm	18 cm & 22 cm	165 cm & 216 cm	Butts & Lewis 1982
Saskatchewan	Badger			13 cm			Haug 1985


Jenny Barnett
Figure 3. A former badger burrow, now occupied by burrowing owls (note the many tracks).

REVIEW OF ARTIFICIAL BURROW DESIGNS

In this section, we highlight examples of artificial burrow designs, with the intent of showing the various combinations of components. While all of these designs work, we recognize that the owls may use some designs more than others. All designs and field testing efforts have helped to advance the primary aspects of artificial burrow systems. The differences in specific components have implications for durability and longevity, tunnel slope, issues of access and maintenance, internal space, and potential flooding. In turn, these burrow features have implications for owl use and productivity. A commonality shared by burrow designs is that there is a bend in the tunnel proper; the main intent here is to not allow sunlight to shine, or a predator to look, directly into the nest chamber. In an important comparison study using three chamber sizes and two tunnel sizes, Smith and Belthoff (2001) found that chamber size and tunnel dimensions strongly influenced nest-site use, with owls using the largest nest chambers (plastic tubs of 50 x 35 x 40 cm, 1,750 cm^2) and the smallest (10 cm. diameter) tunnels. They stated that this combination reduced the negative effects of overcrowding, gained the most favorable microclimate for developing juveniles, and helped to deter larger ground-dwelling predators.

1) *First design by Collins and Landry (1977), California.* The nest chamber was made of warp-resistant plywood and measured 30 x 30 x 20 cm (12" x 12" x 8") deep (Fig 4). The tunnel connecting the chamber to the burrow entrance was 10 x 10 cm (4" x 4") and approximately 1.8 m (6') long with one right-angle turn about 10 cm from the entrance. The sides and top of the nest chamber and tunnel were of wood with a natural dirt floor. The actual dimensions were not felt to be critical, but at least one turn in the tunnel seemed necessary to maintain the nest

chamber in darkness. The whole artificial burrow was buried to a depth of 15 cm to provide thermal stability in the nest chamber. Some flooding and silting in of unoccupied burrows was caused by winter rains; thus most burrows had to be renovated prior to each breeding season. Subsequent to this paper, field test have found that burrow/chamber dimensions are indeed critical, and that the generally poor durability of a wooden structure is also a consideration.

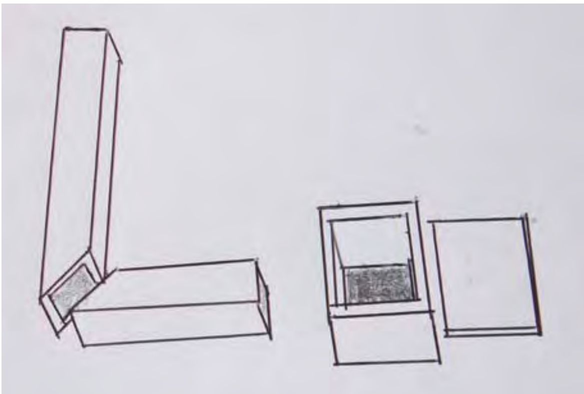


Figure 4. Nest burrow design of Collins and Landry (1977).

2) *Design by Poulin et al. (2001), as used in Canada.* The design by Poulin *et al.* (2001) (Fig. 5) follows the aspects of natural burrows used by owls in Canada: Natural nest burrows have an elevated soil mound at the entrance, and have about a 15-cm diameter tunnel entrance. The tunnel normally extends between 2-3 m and descends to about 1.0 to 1.5 m depth before meeting with a larger 'domed' chamber. The tunnel usually takes at least one sharp turn and often has one rise in elevation before meeting the nesting chamber (this likely prevents flooding). The nesting chamber is 25 to 30 cm tall and at least as wide on all sides.

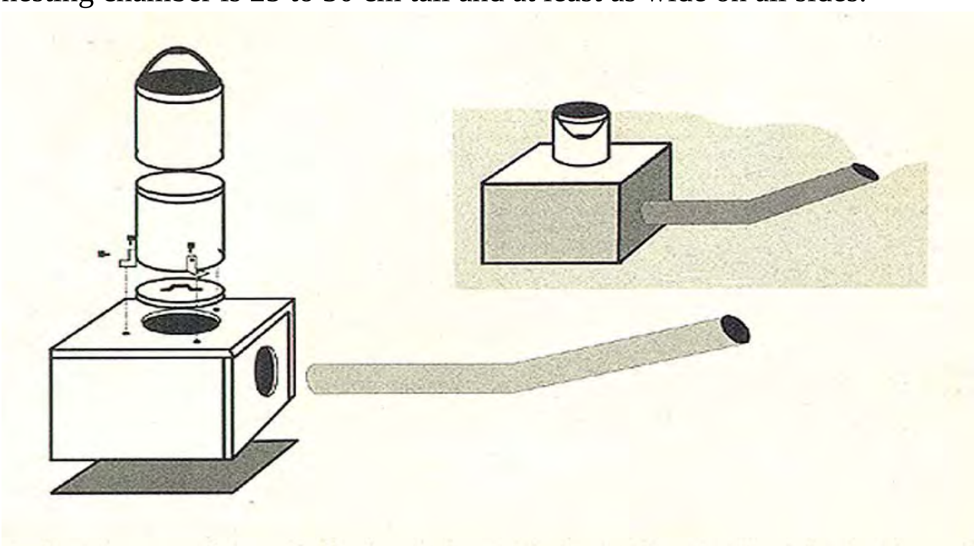


Figure 5. ABS design by Poulin *et al.* (2001) as used in Canada.

3) *Design by Barclay (2008) in California.* The design by Jack H. Barclay (2008) (Fig. 6) conforms to Smith and Belthoff's (2001) findings, using inexpensive, commercially available materials that require minimum modification to assemble into a functional AB. This design also

includes a provision to protect the AB entrance so that when properly installed, the entrance (a hollow concrete end block) is resistant to damage from agricultural machinery and livestock (Smith and Belthoff 2001). Previous AB designs using wooden nest boxes are subject to rotting and collapse and can be time-consuming to construct. Plastic buckets or pails installed as nest boxes are subject to collapse from settling and shifting soil and do not provide the larger nest chamber that Burrowing Owls in Idaho selected (Smith and Belthoff 2001). The plastic irrigation valve box used for the nest chamber in this design provides 1,680 cm^2 of floor space. Bucket collapse can be mitigated, somewhat, by carefully-supervised installation (J. Lincer, pers. comm.).

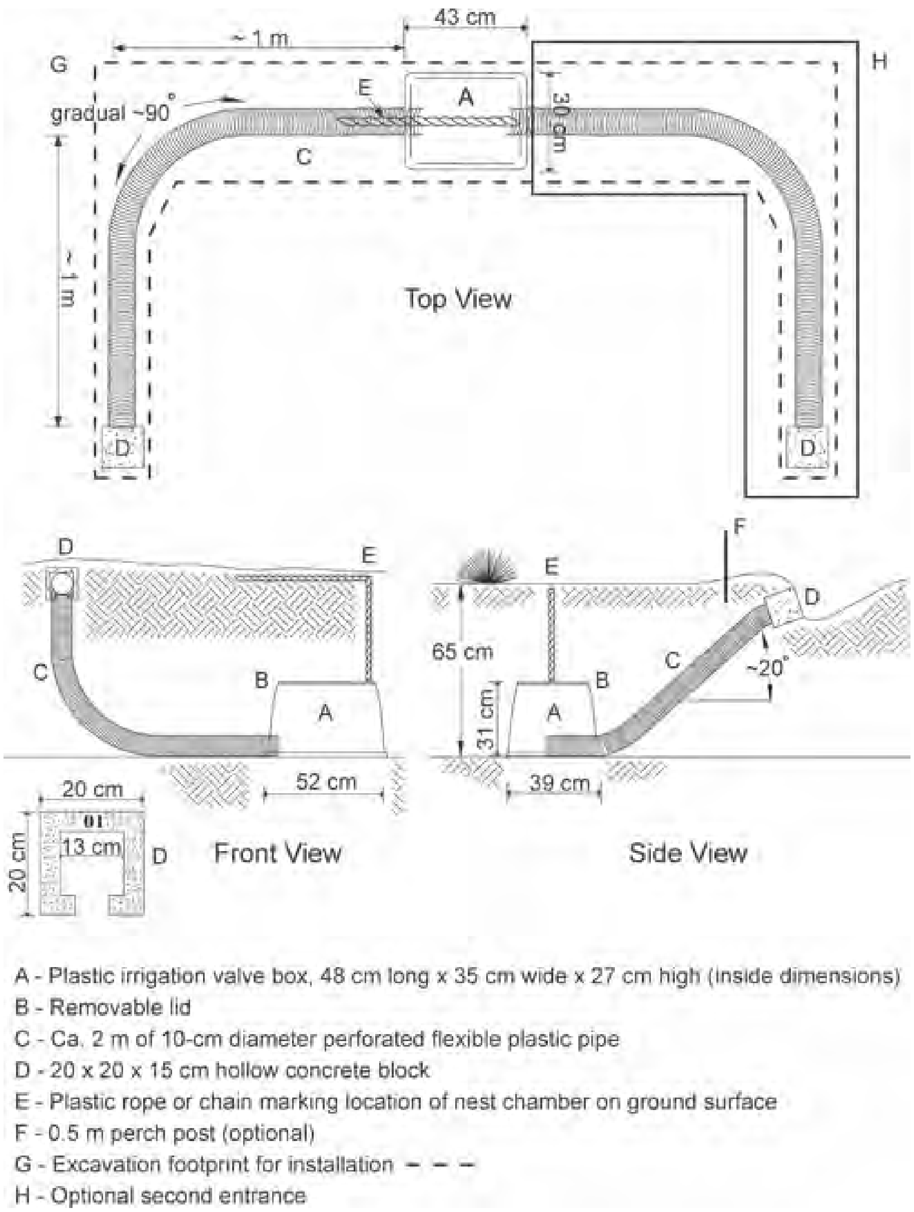


Figure 6. Artificial burrow system design by Barclay (2008).

4) *Design used and updated by Wildlife Resources Institute (California).* Below are design drawings for the burrow system being used by the Wildlife Resources Institute (California) (Fig. 7). Materials: for each burrow, two five-gallon heavy duty plastic buckets with lids (Home Depot), two 8 ft foot lengths of 4” slotted plastic drainage pipe, two 6” to 4” reducers, two one foot lengths of 6” slotted plastic drainage pipe, two hexagonal concrete surround pieces, duct tape, 60 in. wooden post (2” in diameter), and one cement stepping stone at least 1’ square.

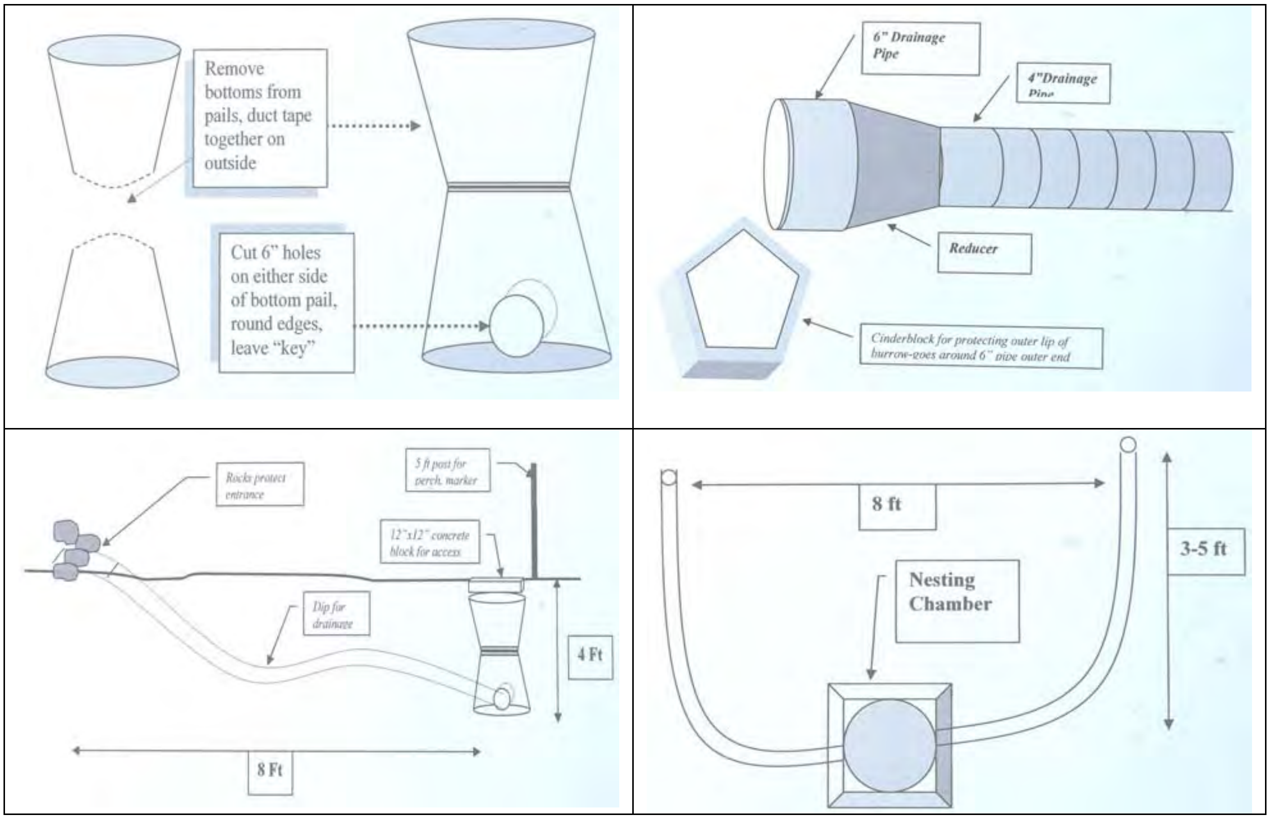


Figure 7. Design drawings for the burrow system being used by the Wildlife Resources Institute (California).

5) *Design from Arizona Partners in Flight Habitat Substitution Project* (Greg Clark 2001, http://www.mirror-pole.com/burr_owl/bur_owl1.htm) (Fig. 8). An underground burrow is built using a 5-gallon plastic bucket for the burrow chamber and 12’of 4” flexible irrigation hose for the tunnel. For protection from dogs, a rigid PVC pipe must be used to protect the burrow entrance (slipped over the 4 in. line). Holes must be provided in the bucket and hose to allow water to escape into the ground, the flexible hose can be purchased with perforations. In addition, the hose must make a double turn between the burrow and the surface to simulate natural burrows. The diagram only shows the tube bending toward the surface, but it also needs to bend horizontally 90 degrees. The section from the burrow chamber to the bend should be at a 4-foot depth. There must be at least two feet of dirt on top of the over-turned bucket. The photo shows the bucket and hose before being buried. Four of these burrow units are installed at a given site (within 5-10 m of each other). Concerns of this design are that the nest chamber is small, and it does not allow for easy inspection or maintenance.

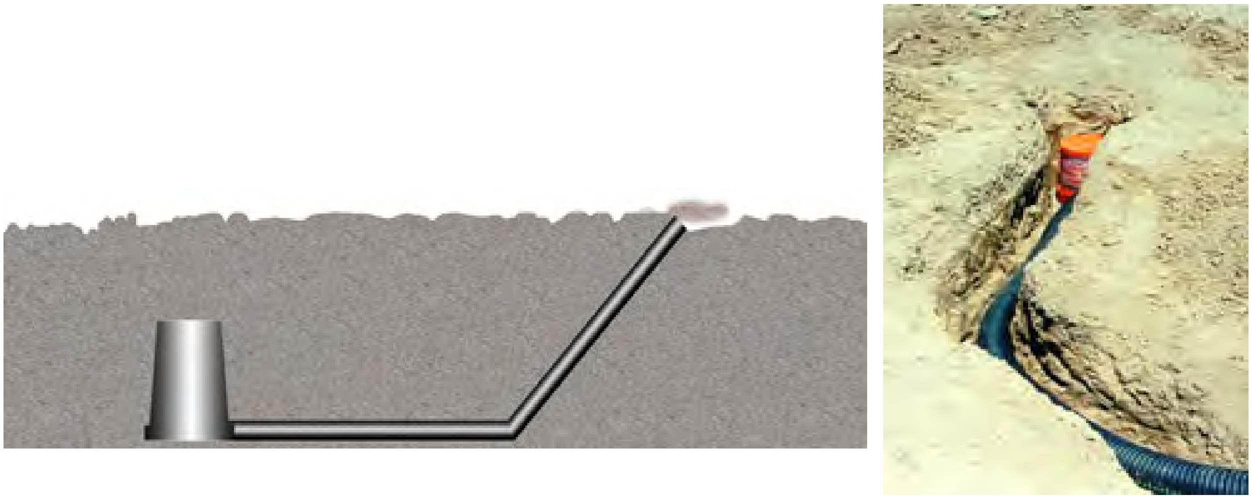


Figure 8. Artificial burrow design from Arizona Partners in Flight Habitat Substitution Project (Greg Clark 2001, http://www.mirror-pole.com/burr_owl/bur_owl1.htm).

6) *Design description as per Belthoff and Smith (2001).* Studies using artificial burrows (Smith and Belthoff 2001, Belthoff and Smith 2003) have documented that burrowing owls prefer artificial burrows with large (68-Liter) chambers and small-diameter (10 cm, 4") tunnels. They placed three artificial burrows in a cluster at previously used natural burrows, and tested for chamber size preferences (Fig. 9). Within the clusters of three, each artificial burrow consisted of a 15 cm diameter tunnel made of flexible, perforated plastic pipe and a plastic nest chamber. Each cluster had chambers of three sizes: a 30 cm x 30 cm x 20 cm (17-L, 4.5 gal, 900 cm^2 floor space) plastic container, a 19 L (5 gal) bucket with a 30 cm diameter (706 cm^2 floor space), and a 50 cm x 35 cm x 40 cm (68 L, 18 gal, 1,750 cm^2 floor space) plastic tub. All ABS tunnels were 2 m long with a 90 degree turn between the entrance and the ABS chamber. Each tunnel sloped downward (20-30 degrees) towards the chamber, within the range typical of nest burrows in their Idaho study areas (Belthoff and King 2002). The tunnel inserted into the chamber on a level plane. The top of each ABS chamber was at least 30 cm underground. To increase the probability of ABS use, a wooden perch was placed in the center of the cluster as in King (1996). From 1997-2001, Belthoff and Smith (2003) monitored 80 ABS clusters (2 or 3 ABS per cluster) and found an annual occupancy rate of 55%, with 33% of the clusters used in four or more years. Their results indicated that artificial burrows provided long-term nest sites for owls.


James R. Belthoff
Figure 9. Clusters of artificial nest burrows used in field comparison studies, Idaho.

OUR SUGGESTED DESIGNS

We suggest two ABS designs, and with the exception of the tunnel size, the units are essentially the same. The designs employ the use of half of a 208 l (55-gallon) barrel for the nest chamber, i.e., 50 cm (20 in.) in diameter (1,960 cm^2 interior floor space) and two stacked 9.5 l (2.5 gal.) buckets on top for access (see Fig. 10 through Fig. 26). We suggest using black- or blue-colored plastic barrels. The floor of the main chamber is located 91 cm (36 in.) below ground level. The main tunnel is a 3.0 m (10-ft) section of 15 cm (6 in.) diameter corrugated flex drain pipe with a 7.5 cm (3 in.) slot cut out of the bottom to provide a dirt walkway for the owls). The occupancy rate of this design through the 2010 nesting season (with 59 units in place) on a northeastern Oregon study site has been 86%. Liquid Nails (or similar adhesive) is used to seal the bottomless bucket to the main chamber, as well as attaching (for the 15 cm design) a tunnel collar to the main chamber. Our second design is this same concept, except that we suggest a 10 cm (4-in.) diameter flex pipe main tunnel without a walkway slot cut out of it.

As owls have shown a clear preference for sites that have many burrows (e.g., Poulin *et al.* 2005), a minimum of two (or three) burrow units should be placed at a given site (5-10 m apart) to make a burrow cluster. One burrow is for nesting and the other as prey cache for male, or refuge for the young; dispersing young use satellite burrows in the vicinity of their natal burrows for about two months after hatching before departing the natal area (King and Belthoff 2001). Burrow clusters are typically placed a minimum of 110 m (Green and Anthony 1989) to 300 m apart, to minimize territorial conflicts and nest abandonment by neighboring owl pairs. The tunnel inserts into the chamber on a level plane. About midway along its length, the tunnel has a 60º arc in it. This provides darkness in the nest chamber, but still allows researchers to readily secure adult and young owls for banding. Further in this Users Guide, we make recommendations as to selection criteria for placement of the ABS system, specifics on placement of short perches (i.e., $\leq$60 cm, 24 in.), and related anti-predator aspects.
Slope of the burrow tunnel entrance: The slope of the burrow entrance is the deviation from horizontal, i.e., the larger the angle, the steeper the entrance tunnel. The slopes of natural burrows in Idaho used by nesting owls was 27º (Smith and Belthoff 2001) and the odds of

burrow use decreased 17% with each 1° increase in slope (Belthoff and King 2002). The slope of the burrow entrance was 15º to 25º in Oklahoma; while steeper-sloped tunnels were available, they were not used by owls nesting in a prairie dog town (Butts and Lewis 1982). Tunnel slope was 15º in owl nests located in California (Coulombe 1971). We suggest that tunnels be gently sloped downward (15-20º) towards the nest chamber.

CONSTRUCTION TECHNIQUE

Materials for our main burrow design:

- One-half of a 55 gallon plastic barrel
- Two – 2.5 gallon buckets
- 16” section of 6” unperforated drain line
- 10’ section of 6” unperforated drain line
- About ½ tube of Liquid Nails
- Jigsaw, skillsaw, drill with ½” bit.
- Anti-predator Patio (see this document for design).

Materials for our second burrow design:

- One-half of a 55 gallon plastic barrel
- Two – 2.5 gallon buckets
- 10’ section of 4” unperforated drain line
- About ½ tube of Liquid Nails
- Jigsaw, skillsaw, drill with ½” bit.
- Anti-predator Patio (see this document for design).

Figure 10. Eighteen artificial burrows ready for placement into the field. Typically, 2-3 burrows are placed 5-10 m (15-30 ft) apart to form a cluster. In turn, each cluster will support one pair of owls and young.

Figure 11. 55-gallon plastic juice barrel with masking tape to mark centerline. One barrel will yield two nest burrows.

Figure 12. Cutting barrel in half with skillsaw.

Figure 13. Trace outline of 2.5 gallon pail bottom onto top of barrel section.

Figure 14. Use jigsaw to cut hole for pail to just slip about 1 in. into barrel.

Figure 15. Use jigsaw to cut bottom out of one 2.5 gallon pail.

Figure 16. Bottomless pail fits into barrel top.

Figure 17. Use caulking gun to apply ample Liquid Nails (or similar adhesive) to solidly affix pail to barrel.

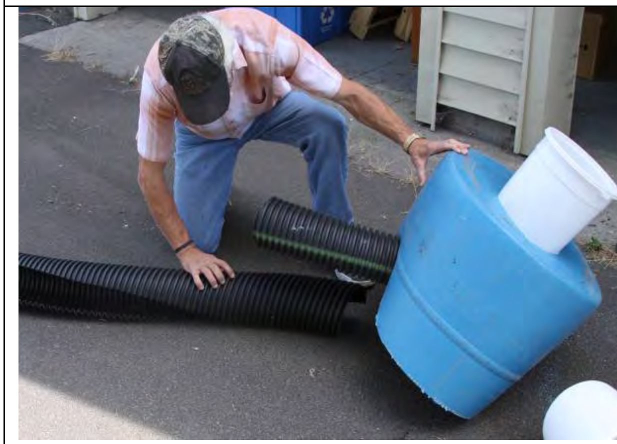
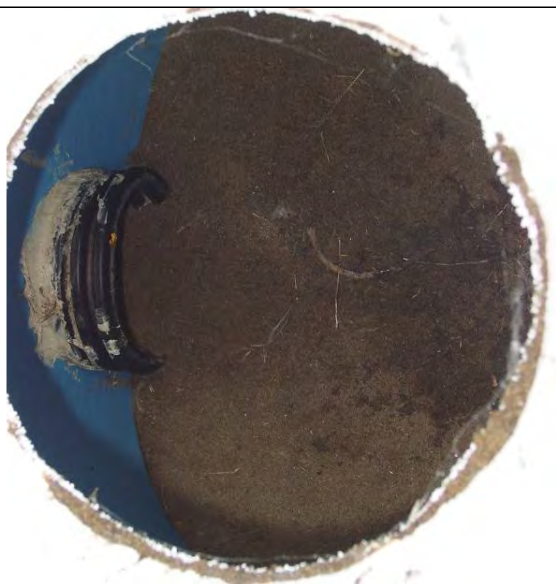
Figure 18. Scribe a 5.75 in. hole onto bottom edge of barrel for the 6 in. drain line collar section. Note: a smaller hole is cut for the 4 in. drain line design.

Figure 19. Cutting the 5.75 in. hole with jigsaw.

Figure 20. Cutting a 3-in. "walkway" in the 15 cm flex pipe with jigsaw (note: a jigsaw works best for this task).

Figure 21. Insert the 6 x 16 in. drain line collar section 2-3 rings into barrel; affix firmly with adhesive, inside and outside of barrel. This needs to be solid.

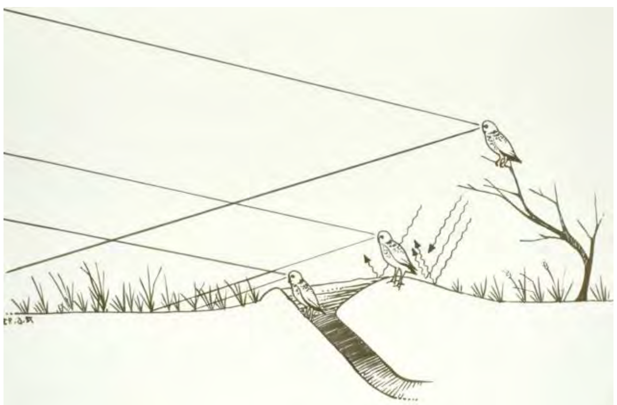
Figure 22. 10-foot tunnel section of 6-in. flexible drain line. A 3 in. wide "walkway" has been cut out. This will be placed face-down, so the owls can walk on natural dirt. A jigsaw is used to cut the walkway out of the flex pipe.

 Figure 23. Test fitting the tunnel section *into* the collar. The final attachment of the tunnel to the collar and nest chamber is done in the field, after the hole has been dug and the nest chamber has been placed into it.	 Figure 24. Test fitting (continued). It is important that the main tunnel be placed on the *inside* of the collar, to aid in future operations of the burrow system. Main tunnel should fit 2-3 rings inside the main barrel chamber. No caulking is used to attach main tunnel section to collar/nest chamber.
 Figure 25. Looking down through pail at tunnel and collar into an installed burrow. Note the amount of adhesive placed around collar fitting; it is important that the collar stay firmly attached to the barrel chamber to prevent water and sand/dirt infiltration.	 Figure 26. Finished burrow chamber, top buckets, and collar. Unit is being installed.

Choosing the Site for Your Artificial Burrow System

In this section we focus on characterizing burrow site selection at the nest site and landscape levels.

Gregory A. Green



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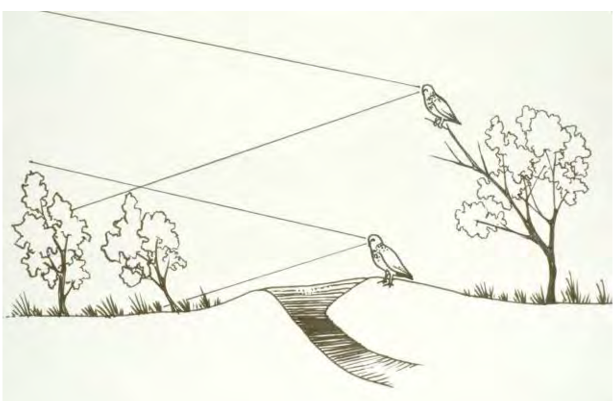


Gregory A. Green

Figure 27. Conceptual diagrams (left column) of the open visual sightline characteristics of critical importance for successful burrowing owl nest sites (G.A. Green pers. comm.). These sightline characteristics allow the owls to detect potential predators and are required for positive owl use of ABS.

The owl's selection of open habitat, lacking dense vegetation and cover, provides the owl high visibility, both for specific foraging needs and predator detection; favored nest burrow sites are those in areas with low vegetation around the burrows (to facilitate the owl's view and hunting success) (Fig. 27). In addition to burrows, the owls also require perching locations and frequently use the top of low mounds (e.g., 17-20 cm; Belthoff and King 2002, Poulin *et al.* 2005) or short perches ($\leq$60 cm) outside (in front of) the burrow.

Gregory A. Green

Figure 28. Good burrowing owl habitat in northeastern Oregon.

Burrowing owl populations have declined in much of the western U.S. and Canada. For example, in San Diego County, California the burrowing owl population decreased approximately 90% between the late 1970s and 2003 (Lincer and Bloom 2003). In order to hypothesize as to what caused the burrowing owl crash and be in a position to intelligently manage this species, one must understand what the important site characteristics are (Lincer and Steenhof 1997, Lincer 2005). Based on our experience, that of others, and a review of the literature, we offer some components considered critical if a site is to support burrowing owls.

1. **Short Grass/Open Space.** *We can't emphasize the importance of this parameter enough.* In order for these ground-dwelling owls to be successful at spotting and catching prey and seeing predators before they become prey themselves, their habitat must contain substantial short grass areas and/or open space, especially close to the burrow(s) (Bloom 1980, Green and Anthony 1989, Poulin *et al.* 2005). This need is emphasized by the fact that burrowing owls commonly leave an area once grazing pressure has been removed and the grass grows taller (J. Lincer and P. Bloom, pers. observ.). The loss of short grass prairie and other habitats with suitable open space is exacerbated through habitat fragmentation (James *et al.* 1997) and the placement of utility poles or trees, in an otherwise flat, open habitat, making owls more easily preyed upon by aerial predators.

2. **Burrows.** Burrows are equally key components of burrowing owl habitat (Henny and Blus 1981). These can be in the form of the classic burrows created by fossorial mammals, artificial burrows, culverts or piles of concrete or other debris that provide

spaces for nesting. Owls use modified environments such as capped landfills, airports, golf courses, etc. For "urban owls," these may be useful sites for relocation, etc. However, in order that a burrowing owl population be truly self-sustaining, a healthy fossorial mammal population is helpful, if not critical, over the long term. This being the case, the type of soil can be critical, since these small mammals can only dig where there's an adequate soil structure to prevent cave-ins but not so much clay or rock that they can't dig into it. Burrowing owls have demonstrated their preference for nesting in places that have a higher-than-average supply of nest burrows (e.g., Poulin *et al.* 2005).

3. **Prey.** An adequate supply of prey, with enough diversity to meet the food needs of the owls throughout its life cycle, is clearly critical. This usually means a healthy mix of arthropods, small mammals**,** birds, and reptiles. For owls to over-winter on or near the breeding grounds, the prey base needs to be adequate *throughout the year*. As an example, the colony on North Island (San Diego County), which consistently had high nesting success, experienced very poor reproduction in 1999, when winter rains (and, presumably prey) were very limited. Specifically, 60-70% of the burrowing owl pairs failed to produce any young that year (C. Winchell, U.S. Fish and Wildlife Service, pers. comm.). In northeastern Oregon, small mammals are the main prey during incubation to fledging. However, about the time of fledging, the small mammals begin estivation, requiring the owls to switch to grasshoppers and other insect prey.

4. **Conflicts with Listed Species Management.** In some areas of the owls' range, conflicts between the management of two (or more) species, both in need of intense action, is not uncommon. Interactions between peregrine falcons and least terns are a classic example. So it is with burrowing owls and least terns, and perhaps western snowy plovers, in coastal San Diego, California. Management decisions as to which species gets "managed" are based on the level of legal protection. Since the burrowing owl is listed differently across the U.S. portion of its range, and is not listed as Endangered or Threatened in the U.S., the owl is a species that has been managed against by the responsible agencies in these conflict situations, with the net result being the effective removal (either temporarily or permanently) of those owls from the breeding population. Clearly, the owl is a tri-national conservation issue, with effective conservation efforts needing to take place at the local and regional levels.

5. **Minimal Disturbance.** Burrowing Owls often occupy disturbed environments, most colonies appear to have a finite threshold for human or pet-related disturbance, beyond which colony size reduction and/or abandonment occurs (Wesemann and Rowe 1985, Millsap and Bear 2000). During three years of observing owls that were translocated to artificial burrows in four different land uses, Grandmaison (2007) observed lower site occupancy at artificial burrows located in residential areas and urban parks, compared to those in agricultural and industrial sites in Arizona. Grandmaison also found that if burrowing owls at translocation sites are free from major disturbances (harassment by feral dogs, vandalism, vehicular traffic, changes in vegetation structure), both nest success and reproductive output remain relatively constant regardless of land use. In other situations, some burrowing owl populations seem to be able to tolerate a moderate level of human disturbance. This characteristic may provide a management opportunity in certain situations. The timing and frequency of disturbance is an important management issue. For instance, human activity, including recreation, disking, scraping,

or mowing adjacent to an active burrow may drive the pair away prior to or during egg-laying or incubation but, once they've produced eggs and incubated for a while, they are less likely to leave (because of their parental investment). For this reason, some military bases and public conservation areas with large grassy habitats could provide desirable locations for burrowing owl relocation and other management efforts.

6. **A "Normal" Predator Population.** Natural habitats have been greatly modified since the arrival of Europeans in North America. Burrowing owls have co-existed with their predators for 6.5 million years (Haug *et al.* 1993) to their mutual advantage. However, when a food chain is simplified, internal checks are lost. In coastal southern California, which has lost many of its mountain lions and other top predators, the populations of meso-predators tend to increase without historical controls. In areas that are close to human habitation, pet and feral dogs and cats are added to the list of meso-predators, although they don't seem to be a problem for all areas (e.g., Imperial Valley, D. Rosenberg, pers. comm.). These predators, however, are the very ones that are capable of effectively impacting the burrowing owl, especially through predation of the young.

7. **Predation "Facilitation."** Field observations and the literature indicate that many other raptors are very effective predators of this owl. Habitat changes, such as placement of utility poles or trees in an otherwise flat environment, markedly increases the effectiveness of these aerial predators, making otherwise supportive and surrounding habitat unproductive because of intensive and successful predation on these owls.

8. **Minimum Population Size.** The burrowing owls, themselves, are part of the environment that they create. They are, at least, semi-colonial, if not colonial, nesters. In addition to providing desirable genetic diversity and increased awareness of both predators and prey, having several nesting pairs nearby should also increase success by attracting and keeping pairs around in an otherwise unoccupied area. Long-term burrowing owl colonies are often characterized by a large number of pairs but this may, simply, be a reflection of burrow availability. However, there is some evidence that the owls have behavioral traits to select for this (Ronan 2002). Satellite burrows are clearly a feature of the owls' natural history and they show a strong selection for this trait as a "habitat feature" (Rosenberg, pers. comm.). In our opinion, satellite burrows aren't just peripheral to the needs of burrowing owls; they are important escape routes. If an owl has no place to go *other than its nest burrow*, it is doomed to predation, particularly by avian predators. This, in fact, may be is one of the reasons so many relocation attempts have failed. It is possible that once a population decreases below a certain number, other key benefits of colonial breeding are also lost (e.g., increased predator and prey awareness, maximizing gene pool variability, mutual assistance in the raising of young, etc. (J. Lincer, pers. observation; C. Winchell, pers. comm.). Although this factor is not a causative force in the initial decline of the burrowing owl population, and certainly colonies experience a normal fluctuation in size, a colony may not be as likely to recover once it falls below some critical size, especially if there is no other local colony from which to recruit new individuals (WRI 2003).

Jeffrey L.Lincer

Figure 29. General landscape view of burrowing owl habitat in southern California. The artificial burrow is placed in the rise in lower right-hand edge of the photo.

Jenny Barnett

Figure 30. Flagging marks the sites for installation of two burrows. Notice that the location is on a topographic rise, with a very open, and dominant, view of the surroundings.

Mike Gregg

Figure 31. Completed burrow installation. Note that this site is located on a gentle topographic rise, with the burrow facing to the right. The bitterbrush root wad was brought in for the perch

Burrowing Owl Conservation Society of British Columbia.

Figure 32. Burrow complex at Nikola lake area, British Columbia. Prime residence.

Installation Technique

1) Burrows are installed in groups of two or three, with 15-30 feet between each burrow entrance.

2) Dig the hole for the intended burrow, either by hand or with the help of a backhoe or trencher. . Place dug out dirt close, for easy access to cover hole back up (you will be backfilling by hand). Remove the sod pieces carefully and place them to the side.

3) The pipe should extend inside the nest chamber only 2-3 ribs of pipe. Double check just before final fill-in to ensure pipe has not moved further into the nest chamber.

4) Place dirt in tunnel and/or Insure that the “walkway” notch of the pipe is facing downwards, and backfill gently to hold it in place. Pipe for tunnel is 10 feet long.

5) Place the bucket system deep enough so that the top bucket is at ground level. Put dirt in the top bucket (with handle) with soil.

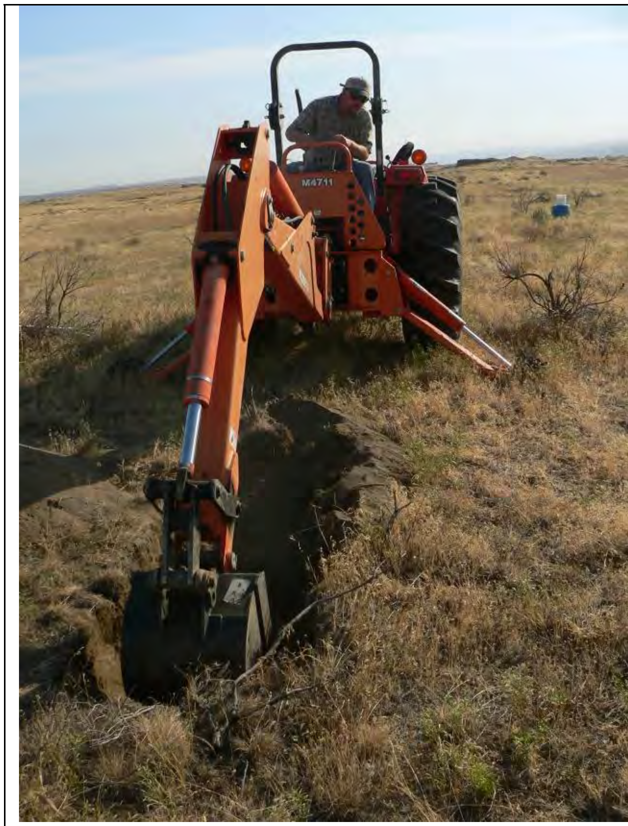
7) Do NOT use backhoe to backfill as the backhoe moves too much dirt at once, and can easily affect the chamber position, or crush/alter the tunnel. Back fill by hand and tamp soil firmly over pipe and around nest chamber. This will prevent the soil from settling and leaving a divot. Replace the removed sod pieces on the disturbed soil areas after the burrow system is installed.

8) If available, place rocks around the entrance to prevent coyotes and dogs from digging. Support each side of the pipe entrance with rocks. This will prevent damage to the pipe by large top rocks. If rocks are not available, place dirt and sod in a small mound (e.g., 10-12 in.es tall) on top of entrance, to hold burrow tunnel in place, and give the owls a place to perch (and view their surroundings). To minimize cattle trampling, place rocks around burrow entrance and nest chamber bucket.

9) Record, date and GPS the new burrow’s location. Write out full GPS coordinates (lat/long in decimal degrees).

10) Tunnels are inserted into nest chambers on a level plane, and the bottom of the nesting chamber is placed 91 cm (36 in.) below the surface of the ground. This depth will insure that the top of the top bucket will be flush with ground level. The top of each nesting chamber is 35 cm (14 in.) underground.

The next series of 12 images show the installation and backfilling process. All backfilling is done by hand. Figure 33 shows a completed burrow installation.



Backhoe digging main hole for burrow chamber; the bottom of the burrow chamber will be 36 in.es below ground level.

Trench for the burrow tunnel is done with a sweeping motion of the backhoe bucket. In this image it is a left-swinging and upward motion. This gives the trench an appropriate arc for the main tunnel. Some hand digging may be necessary (to get the trench deep enough) right where the main tunnel meets the collar/burrow chamber.






David H. Johnson

Figure 33. Newly installed burrow in northeastern Oregon. Note the sod clumps placed on top of the tunnel entrance to make sight mound, the top bucket just protruding out of soil, and natural perches.

PREDATOR-PROOFING YOUR ARTIFICIAL BURROW SYSTEM

We see five main aspects to making artificial burrows more predator resistant:

1) size of burrow entrance
2) the addition of an anti-predator 'patio' at the mouth of the burrow entrance
3) putting rocks around the burrow entrance area to frustrate digging mammals, such as coyotes or feral dogs
4) perch placement
5) attaching a screen mesh to the bottom side of the nest chamber, to frustrate the under-and-up digging of badgers

Size of Burrow Entrance. Burrowing Owls have demonstrated preferential use of artificial burrows with entrance hole diameters of 10 cm. (Smith and Belthoff 2001). Many artificial burrow users have utilized either a 10 cm or a 15 cm tunnel size. In this paper, we recommend the use of a 15 cm tunnel (with a dirt floor), but with a 10 cm passageway (anti-predator patio) added to the burrow entrance (Fig. 34). We also recommend a 10 cm tunnel (especially in areas where owls have historically used ground-squirrel burrows), with a anti-predator patio attached (Fig. 35).

Keppers *et al.* (2008) reported on the use of artificial burrows by Western Burrowing Owls and other vertebrates during winter in southern Texas. They monitored 72 burrows that consisted of equal numbers of 15, 20, or 25 cm diameter, 2.4 m-long perforated polyethylene drainage pipe. Of their 58 owl detections, 46 (79%) occurred in the 15 cm dia. pipes. Wintering owls were usually observed roosting at the entrance (not the interior) of the burrows, supporting the hypothesis that owls selected 15 cm-diameter artificial burrows primarily because they deter large mammal predators. Also, in the 15 cm dia. pipes, they recorded one sighting of a Virginia Opossum (*Didelphis virginiana*), and four sightings of the Striped Skunk (*Mephitis mephitis*). Both of these two mammal species are potential nest predators of burrowing owls, noteworthy here is that they were able to gain access through the 15 cm dia. pipes.

Anti-Predator Patio. Wellicome *et al.* (1997) put predator-excluder "collars" (also called 'donuts') inside the burrow tunnels, about 30 cm (12 in.) in from the entrance. For the three years of their study, predator-proof burrows significantly reduced the frequency of nest predation.

After analyzing burrow opening sizes, actual tunnel dimensions of the fossorial burrow makers, and observations of burrowing owls as they dash into burrows to avoid danger, we felt it justifiable to design an addition onto the ABS tunnels. The anti-predator patio is designed to allow several owls (say a family group of young) to quickly move inside a covered area (and then go single-file into the main tunnel), but still provide a limited (i.e., 10 cm.) portal that will exclude many mammalian predators. We offer two designs for this (Fig. 34 and Fig. 35) with one design for 15 cm tunnels, and the other for 10 cm tunnels. If we were to only use a 10 cm tunnel (with no patio), the young will 'bunch up' at the entrance, and it is probable that any avian (and some mammalian) predators will capture an unlucky 'not-quite the last in' owl. Also, the entrance of a 15 cm diameter tunnel has been observed as a safe roost, the size most frequently used by wintering owls (Keppers *et al.* 2008).

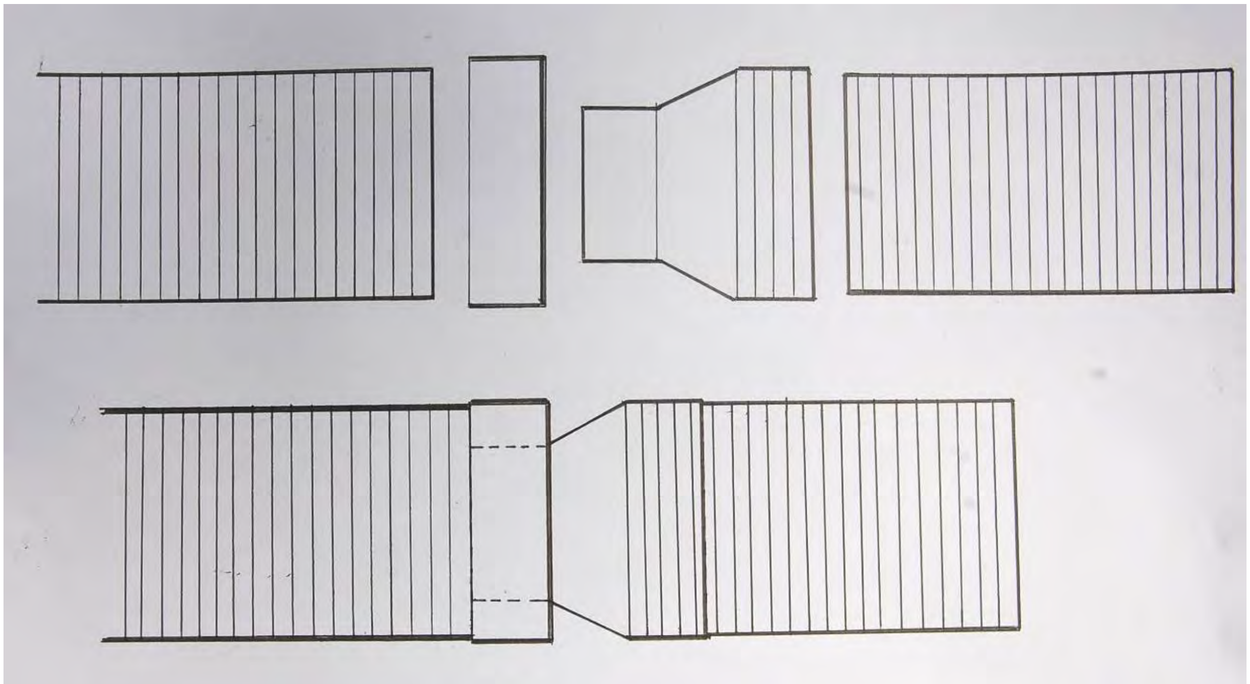


Figure 34. *Anti-predator patio for 15 cm(6 in.) tunnel.* Top drawing shows the four components for the anti-predator patio (L to R): 6 in. dia. main tunnel, a 6 in. cap (with 4 in. dia. hole cut out of it), a 4-to-6 in. connector, and a 6 in. dia. x 12 in. patio section. Liquid Nails (or similar adhesive) is used to connect the cap, connector, and patio section together so they become a solid unit. Bottom image shows the completed patio unit. Entrance is from the right. About 1 in. of dirt is placed inside the patio unit and tunnel to level the walkway for the owls. The exact dimensions of these components may vary based on the materials available in your location.

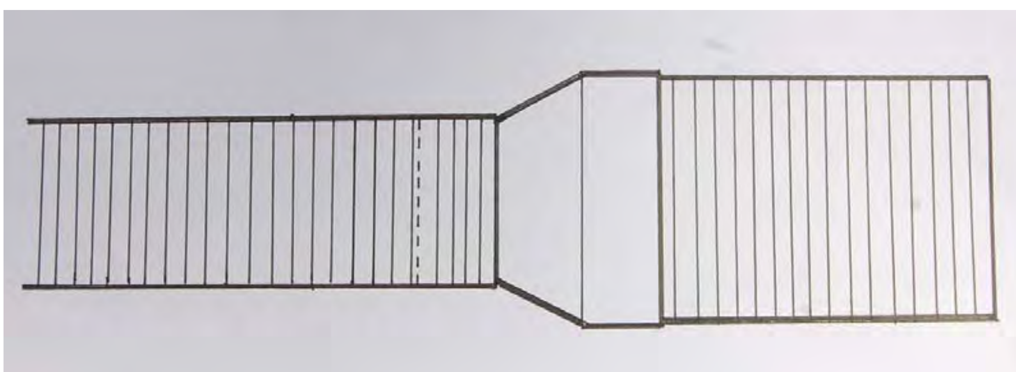


Figure 35. ***Anti-predator patio for 10 cm (4 in.) tunnel.*** Drawing of completed anti-predator patio unit with the 3 components: 4 in. main tunnel, a 4-6 in. connector, and a 6 in. diam. x 12 in. long patio section. About 1 in. of dirt is placed inside the patio unit (and a lesser amount in the tunnel) to level the walkway for the owls. Entrance is from the right.

Perches for the Owls. Perches, and mounds, are substantially used by owls for roosting, preening, observing, and hunting. Perches are also used during the very hottest of weather, to help the owls stay cool. Perches should be relatively short in height, e.g., $\leq$ 60 cm (24 in.es).

We found that, in certain situations, a 90-120 cm (3-4 foot) high pole perch we provided was too attractive to ravens but, if we shortened it to 60 cm or less, it *seemed* to reduce its attraction for ravens but the owls still used it. As we don't want the perches to be used to the advantage of avian predators, we urge the placement of the perch *in front of* (not behind) the burrows (Fig. 36). That way, when an owl comes to the entrance (from the inside), it can see if a potential predator is sitting on its hunting perch. If the perch is behind the entrance, the advantage is with the predator. We offer six images of natural and artificial perches below.

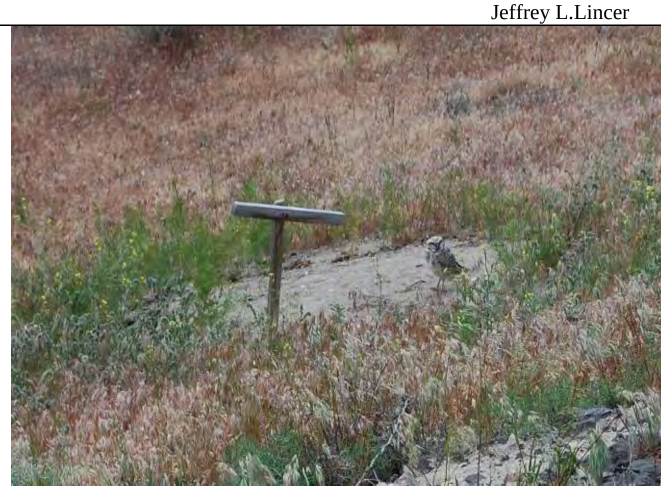
Jeffrey L.Lincer

Figure 36. Perch placement in front of artificial burrow.

Mike Gregg

Jeffrey L.Lincer

Gregory A. Green



Courtney Conway

Jeffrey L.Lincer

Rock around burrow entrances. The digging of coyotes and dogs is often concentrated along the burrow entrances. Armoring the entrance areas with rocks, a piece of concrete (Fig. 37) or placing a slightly larger solid piece of PVC tubing over the first meter or so of the tunnel have been used.

Jeffrey L.Lincer

Figure 37. A well-fortified burrow entrance, to ward off digging by coyotes and domestic dogs.

***Wire grate under burrow chamber*.** Badgers have been reported digging down alongside the burrow chamber, and then under it, to get at the owls within. Thus far, to our knowledge, this type of predation has been reported only from Canada. A remedy for this is the attachment of a wire grate to the bottom of the burrow chamber before it is placed into the site and backfilled (Wellicome *et al.* 1997).

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