HABITAT SUITABILITY AND POTENTIAL CORRIDORS FOR SAN JOAQUIN KIT FOX IN THE SAN LUIS UNIT

FRESNO, KINGS AND MERCED COUNTIES, CALIFORNIA

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ENDANGERED SPECIES PROGRAM

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EXECUTIVE SUMMARY

Vast acreage of agricultural land within the San Luis Unit (SLU) of the Central Valley Project in the San Joaquin Valley of California suffers from soil drainage issues. The U.S. Bureau of Reclamation (Reclamation) is under obligation to assist with disposal of drainage water from these lands. Reclamation has evaluated various alternative strategies for disposing of this water and has selected a preferred alternative. This preferred alternative, the "In-Valley/Water Needs Land Retirement Alternative", involves treatment and reuse of drainage water and also reducing the quantity of drainage water produced by retiring lands from irrigated agricultural production. As many as 194,000 acres may be retired, and these lands potentially could provide habitat for rare species, particularly the San Joaquin kit fox (*Vulpes macrotis mutica*).

The California State University-Stanislaus, Endangered Species Recovery Program (ESRP) conducted analyses to assess habitat suitability for kit foxes in the SLU under current conditions and under the preferred alternative. Under the preferred alternative, potential kit fox habitat would increase from the current 26,102 acres to 104,228 acres. Much of this habitat would occur in contiguous blocks sufficient to support multiple kit fox family groups, which would facilitate kit fox persistence on these lands. A significant caveat is that retired lands will need to be managed in a manner that produces a favorable vegetation structure for kit foxes and their prey. Habitat with relatively low, sparse vegetation is more favorable for kit foxes than lands with tall, dense vegetation. Grazing might be an economically feasible tool for improving habitat suitability for kit foxes on retired agricultural lands. In the absence of appropriate management, the preferred alternative actually might result in a net loss of kit fox habitat in the SLU.

The ESRP also attempted to identify optimal placements for kit fox movement corridors into and through the SLU. Corridor modeling revealed that retiring and appropriately managing lands could significantly enhance the probability of kit foxes colonizing lands within the SLU. The most likely sources of kit foxes would be existing populations in the Ciervo-Panoche and Pleasant Valley-Coalinga regions. Modeling also indicated the importance of conserving the existing corridor, which is quite narrow in places, that connects the 2 source populations.

Based on ESRP analyses, implementing the preferred alternative potentially could result in the eventual establishment of a satellite population of kit foxes in the SLU. However, this potential is strongly predicated on the initiation of appropriate habitat management prescriptions on retired agricultural lands. Retirement and management of agricultural lands within the SLU also would contribute to fulfilling a number of recovery tasks identified in the recovery plan that includes kit foxes. Additional information on the regional status of kit foxes, appropriate ecosystem restoration strategies, beneficial habitat management prescriptions, and prey and competitor response to land retirement, along with the implementation of an outreach program all would enhance the probability of successfully establishing a kit fox population within the SLU.

ACKNOWLEDGEMENTS

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INTRODUCTION

SAN JOAQUIN KIT FOX

The San Joaquin kit fox (*Vulpes macrotis mutica*) historically occupied arid upland habitats throughout the San Joaquin Valley. These habitats include saltbush scrub, grasslands, and alkali sink. Former and current conversion of these habitats to agricultural, industrial, and urban uses has resulted in profound habitat degradation, fragmentation, and loss. As a result, the San Joaquin kit fox was listed as Federally Endangered in 1967 and California Threatened in 1973 (U.S. Fish and Wildlife Service 1998).

Kit foxes currently persist in a metapopulation consisting of 3 larger "core" and a number of smaller "satellite" populations (U.S. Fish and Wildlife Service 1998). Movement of foxes between these populations is critical for maintaining genetic and demographic exchange. Habitat loss and fragmentation result in small populations that are subject to increased risk of extinction due to catastrophic or random demographic events. Thus, movement corridors are essential to prevent local extinctions of foxes and to allow recolonization of lands where foxes are extirpated or lands where habitat has been restored.

SAN LUIS UNIT AND PROPOSED DRAINAGE FEATURE RE-EVALUATION PROJECT

The San Luis Unit (SLU) is a water service unit within the Central Valley Project. The Federal manager for the Unit is the West San Joaquin Division, South-Central California Area Office of the Mid-Pacific Region of the U.S. Bureau of Reclamation (Reclamation). The Unit is located in the west-central portion of the San Joaquin Valley (SJV) in California and encompasses portions of western Kings, Fresno, and Merced Counties (Figure 1). The Federal role within the Unit is to provide approximately 1.25 million acre-feet of irrigation water for use on approximately 600,000 acres (U.S. Bureau of Reclamation 2007*a*).

Within the SJV, many agricultural lands are characterized by drainage problems. In short, due to high concentrations of soil salts and poor soil drainage associated with heavy clay soils and hardpan formations, agricultural production is adversely impacted by shallow water tables with high ground water selenium concentrations unless lands are properly drained (Ritter and Lair 2007). Within the Unit, approximately 379,000 acres require drainage (U.S. Bureau of Reclamation 2007*b*). As a result, large quantities of agricultural drainage water are generated. A significant issue then becomes disposal of this agricultural drainage water. Reclamation is obligated to provide drainage services to the San Luis Unit. Among other requirements, these services need to be provided in a manner that minimizes adverse environmental effects and risks (U.S. Bureau of Reclamation 2007*b*).

Reclamation developed 8 alternative strategies for potentially addressing the drainage water disposal issue in the Unit (U.S. Bureau of Reclamation 2007*b*). These alternatives included a "no action" option, 4 "in-valley" disposal options, 2 Sacramento-San Joaquin Delta (Delta) disposal options, and a Pacific Ocean disposal option. All of these alternatives were thoroughly

evaluated in an Environmental Impact Statement, and a preferred alternative was selected (U.S. Bureau of Reclamation 2007*b*).

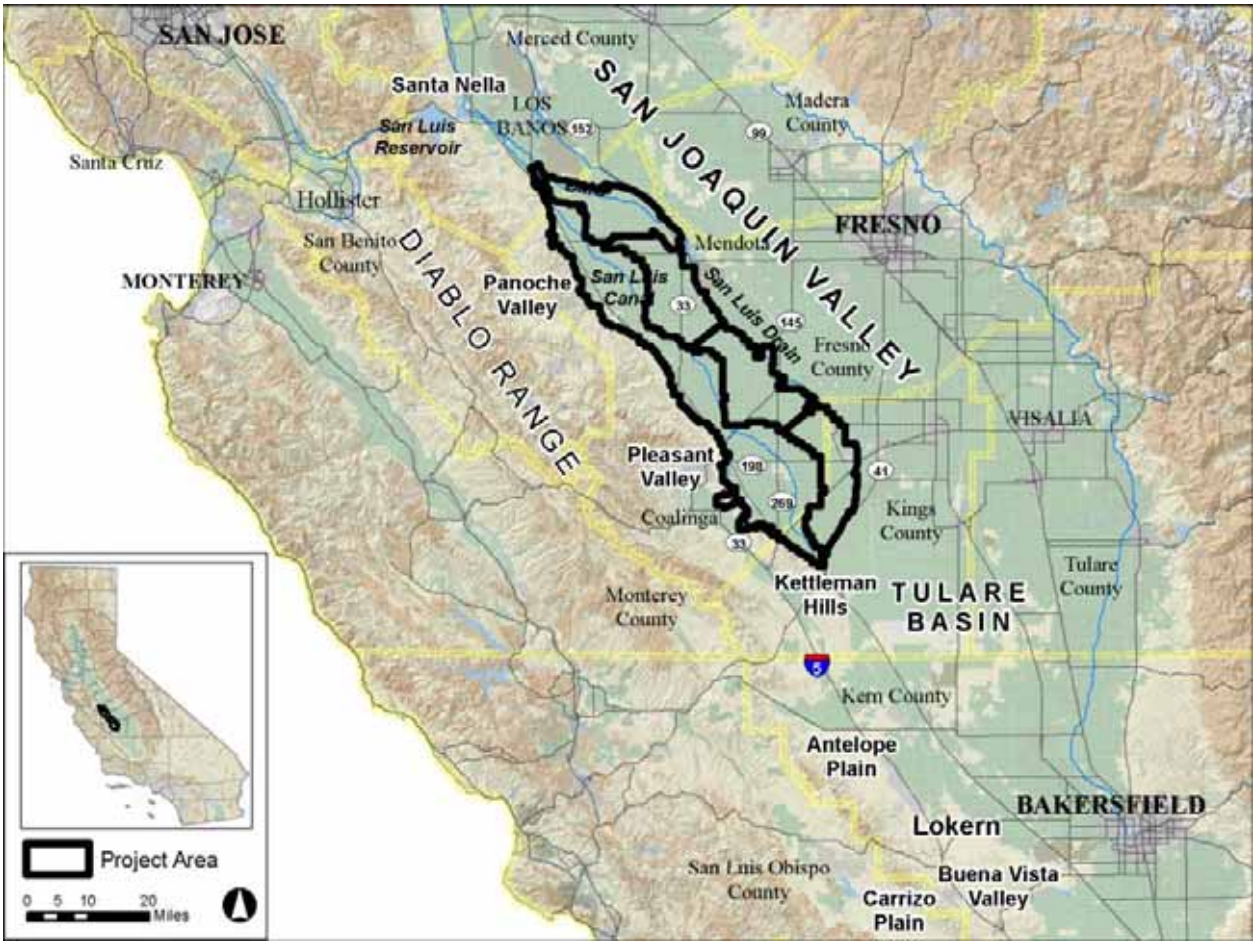

Figure 1. Location of the San Luis Unit.

The preferred strategy for disposing of drainage water within the Unit is referred to as the "In-Valley/Water Needs Land Retirement Alternative" (U.S. Bureau of Reclamation 2007*b*). This plan includes drainage reduction measures, drainage water reuse facilities, treatment systems, evaporation ponds, and the retirement of 194,000 acres of land from irrigated crop production (of which, 44,106 acres have already been retired). In a Biological Opinion issued by the U.S. Fish and Wildlife Service (FWS) in 2006, the FWS determined that the strategy above would not jeopardize the continued existence of the San Joaquin kit fox, and provided reasonable and prudent measures (including terms and conditions to implement the measures) to minimize take of kit foxes (U.S. Bureau of Reclamation 2007*b*). One of the terms and conditions is:

> "(1) San Joaquin Kit Fox (d): When planning and siting the retired lands that are to be used for grazing, Reclamation shall give priority to lands identified by the ESRP and the U.S. Fish and Wildlife Service that would maximize their utility for kit fox recovery when such lands also meet Project goals to reduce contaminated drainage."

GOAL AND OBJECTIVES

The California State University-Stanislaus, Endangered Species Recovery Program (ESRP) is assisting with the fulfillment of this term and condition by conducting analyses of habitat suitability for kit foxes and potential corridor placement within the Unit. The goal of this effort is to provide guidance on the effects of the proposed activities on regional habitat suitability and habitat connectivity for San Joaquin kit foxes.

Specific objectives are to:

1. Assess habitat suitability for kit foxes under (a) current conditions, (b) the preferred drainage alternative without associated habitat management, and (c) the preferred drainage alternative in association with habitat management to improve suitability for kit foxes.
2. Identify optimal placement of movement corridors to encourage colonization of retired agricultural lands by kit foxes and to facilitate demographic and genetic exchange between fox populations in retired lands and existing natural lands.

METHODS

HABITAT SUITABILITY

Current habitat suitability

We measured habitat suitability for San Joaquin kit fox on lands within and adjacent to the SLU based on a combination of land use and physical landscape properties (terrain ruggedness and vegetation density). Land use values were measured using a geographic information system (GIS) dataset of land use with data derived from the California Department of Water Resources (DWR) Land Use Survey data (DWR 2006). We reviewed air photos of the study area (UDA-FSA-APFO 2006) and conducted reconnaissance surveys to identify lands converted from field crops to permanent crops (orchards or vineyards) subsequent to the source land use data.

DWR land use data is used to measure water use and does not typically include detailed vegetation classes for non-irrigated "natural" lands (classified as *Native Vegetation*). We developed a land use classification model to assign vegetation community classes to *Native Vegetation* lands based on secondary map sources (U.C. Santa Barbara 1998, U.S. Fish and Wildlife Service 2006).

We assigned habitat suitability values (model weights) based on previous studies of kit fox utilization of natural, agricultural, and urban lands and by evaluating common landscape features of lands consistently used or occupied by kit fox. We assigned values of 0-100 to series of land use categories (e.g. row crops, orchards, residential) and used these to classify the relative suitability of GIS land use features.

In addition to land use and vegetation community classes, we weighted suitability of natural lands by topographic ruggedness (Valentine et. al. 2004). Past study of kit foxes at Naval Petroleum Reserves in California has shown topographic ruggedness as a "consistent factor that

affected capture rates of kit foxes", with foxes appearing to be most abundant and persisting longest in areas of low topographic ruggedness (Warrick and Cypher 1998). We classified topographic ruggedness using a 30-m digital elevation and classifying areas as rugged according to the differences between each grid cell of elevation and its neighboring cells. The result was classified into four classes with values of 1-100 with high values being the most suitable.

We found that the vegetation community data used did not adequately distinguish between arid grasslands (low vegetation structure and patches of bare ground, Appendix A, Arid grasslands) and grasslands with a less suitable vegetation structure. We estimate structure using a vegetation index derived from satellite imagery (Carroll et. al. 2007). Non-developed or natural lands with dense vegetation were assigned lower suitability values. We did not weight suitability based on vegetation density for developed (agricultural and urban) lands to avoid overestimating suitability based on temporary land management practices (e.g., temporary fallowing of fields or urban land being cleared for development). Rather, the weight value assigned to the land use class included an assumption of the typical vegetation density for class.

Habitat suitability under the Water Needs Alternative

To estimate potential habitat suitability under the Water Needs Alternative, we modified land use features of our GIS based on the locations of retired farmland, evaporation/treatment facilities and reuse areas described in the SLDFRE EIS (U.S. Bureau of Reclamation 2006). The EIS identifies more potential reuse areas than would be needed under the preferred alternative. Because the locations of reuse facilities are not final, we used all potential reuse areas identified in the EIS (U.S. Bureau of Reclamation 2006: Figure 2.3-2). The final configuration of the reuse areas would likely represent approximately 75% of the reuse areas we assumed for our model.

Under the *Terms and Conditions for Incidental Take for Federally-listed Threatened and Endangered Species*, a buffer area of "at least 1.5 km" will be required between reuse areas and retired farmland managed by grazing (U.S. Fish and Wildlife Service 2007, San Joaquin kit fox 1-e,). Based on this condition we classified farmland within one mile of both potential reuse areas and evaporation/treatment areas as land that would serve as buffer area between these areas and grazing lands (Figure 2). We classified remaining lands that fell within the areas identified as "Unserved/Retired Lands" (U.S. Bureau of Reclamation 2006: Figure 2.6-1) in the IES, and currently in seasonal crops as retired farmland managed by grazing.

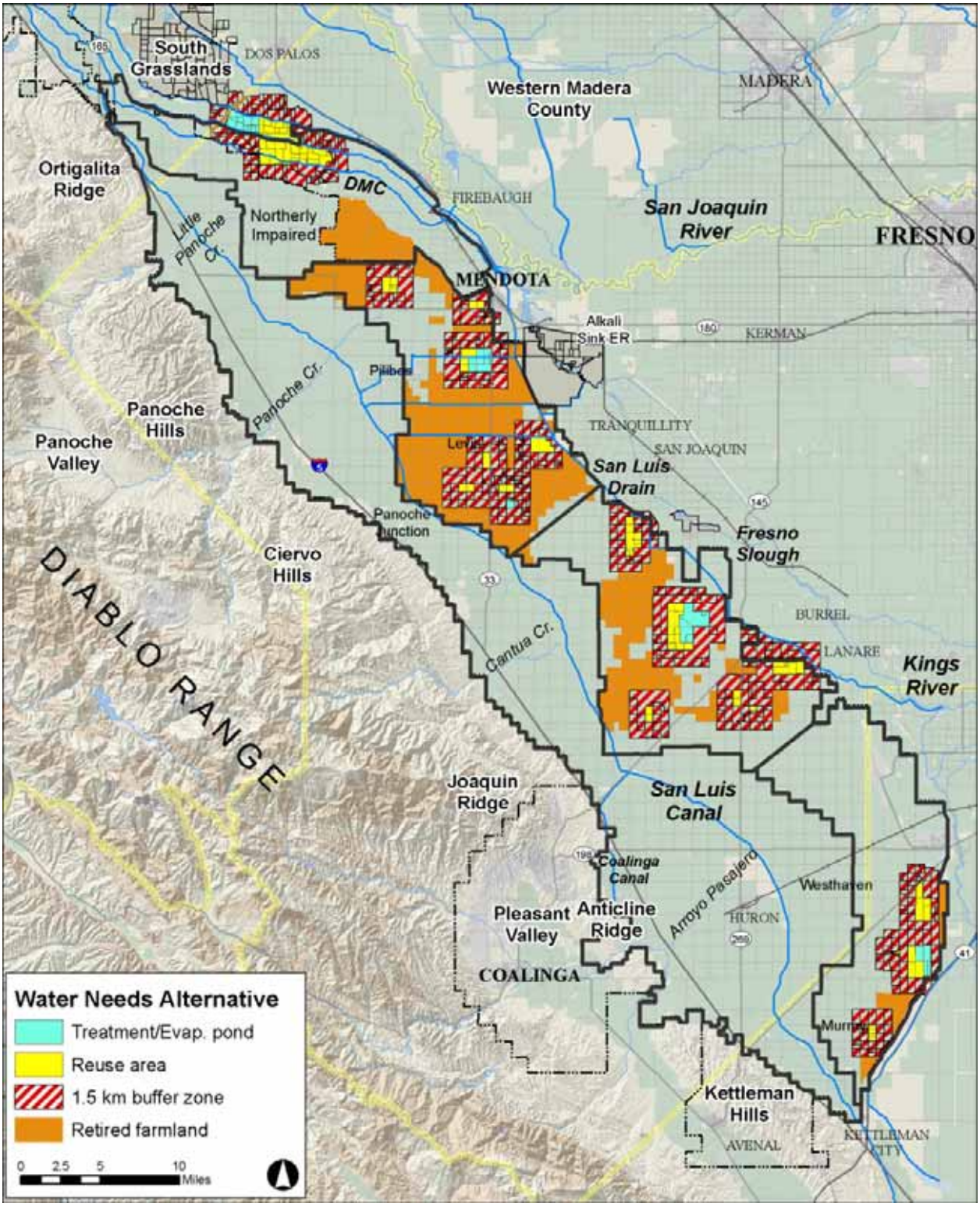

Figure 2. Retired farmland, evaporation/treatment facilities, potential reuse areas, and farmland buffers under the Water Needs Alternative.

POTENTIAL CONNECTIVITY

To identify optimal areas for movement corridors for kit foxes, we developed a GIS model to measure connectivity between large blocks of suitable habitat in the foothill areas west of the San Luis Unit (Panoche Valley and Pleasant Valley, our *source* locations; Figure 3) and isolated islands of suitable habitat on the Valley floor (lands near Alkali Sink Ecological Reserve and in western Madera County, or *destination* locations; Figure 3). We measured connectivity by estimating the *cost distance*, or difficulty of movement though a landscape. Estimation of cost differs from habitat suitability in that we are measuring the potential for movement though landscape features rather than the potential for them to be inhabited by kit fox. For example, a bridge across a canal may not provide suitable habitat for a kit fox, but could be relatively important when looking at connectivity though a landscape. We estimated cost using similar criteria to habitat suitability (land use/vegetation community, topographic ruggedness, and vegetation density) but with weights representing cost of movement rather than suitability.

We combined estimates of travel cost to both the source and destination to generate a *least cost corridor* (Environmental Systems Research Institute 2007) to identify the best available corridor (or corridors) between the source and destination. In a least cost corridor, the best available corridor is represented by lowest values, or those where travel over the landscape accumulates the lowest cost.

To identify optimal areas for movement corridors under the Water Needs Alternative, we generated a second cost corridor based on modified land use features described in section *Habitat suitability under the Water Needs Alternative*.

To allow comparisons between potential corridors and corridors one would find under optimal conditions, we also normalized corridor cost values by dividing them by the length of the single best route, or *least cost path* (Environmental Systems Research Institute 2007). This provided a measure of the mean cost values encountered over the landscape over a corridor route.

RESULTS

HABITAT SUITABILITY

We estimate that there are approximately 5,559 acres of suitable habitat and 20,543 acres of moderately suitable *sub-optimal* habitat currently available for San Joaquin kit fox in the SLDFRE study area (Table 1, Figure 3). Nearly all suitable habitat and most sub-optimal habitat remain along the western edge of the non-impaired lands. On Westlands Water District drainage impaired lands, sub-optimal habitat consists of untilled land managed by grazing, including lands retired under the U.S. Department of Interior Interagency Land Retirement Program near Tranquillity. Other retired lands (leased by water district) were not classified as suitable habitat because we assumed them to be regularly disturbed by semiannual disking based on available lease agreement information (Westlands Water District 2005).

Table 1. Estimated area (in acres) of suitable and sub-optimal available under existing conditions and the Water Needs Alternative.

Sub-area	Existing conditions				SLDFRE Water Needs			
	Suitable	%	Sub-opt	%	Suitable	%	Sub-opt	%
Westlands North Drainage Impaired Lands	0	0.0%	3,890	3.7%	0	0.3%	46,426	23.7%
Westlands Central Drainage Impaired Lands	0	0.0%	300	0.3%	0	0.0%	23,727	18.6%
Westlands South Drainage Impaired Lands	0	0.0%	3,585	3.8%	0	0.0%	5,887	6.0%
Northerly Area Drainage-Impaired Lands	0	0.0%	1,510	1.8%	0	0.0%	10,687	11.3%
Non-Impaired Lands	5,559	1.5%	11,257	3.0%	5,559	1.5%	11,942	3.1%
Total	**5,559**	**0.7%**	**20,543**	**2.7%**	**5,559**	**0.7%**	**98,669**	**12.8%**

Large blocks of suitable habitat west of the study area include the Panoche Valley and areas surrounding the Pleasant Valley near Coalinga. Smaller blocks occur along less rugged creek valleys and low ridges of the Diablo Range (Figure 3). On the valley floor east of the study area, blocks of suitable habitat occur on grazing lands near Alkali Sink Ecological Reserve and in western Madera County (Figure 3).

We estimate that approximately 78,126 additional acres could potentially be made available as moderately suitable or sub-optimal habitat for kit fox under the Water Needs Alternative. Of that, we estimate that approximately 60% (42,536 ac) would occur in the Westlands North area, approximately 33% (23,427 ac) in the Westlands Central area, and smaller amounts (2,302 ac and 9,177 ac) in the Westlands South and Northerly areas (Table 1, Figure 4).

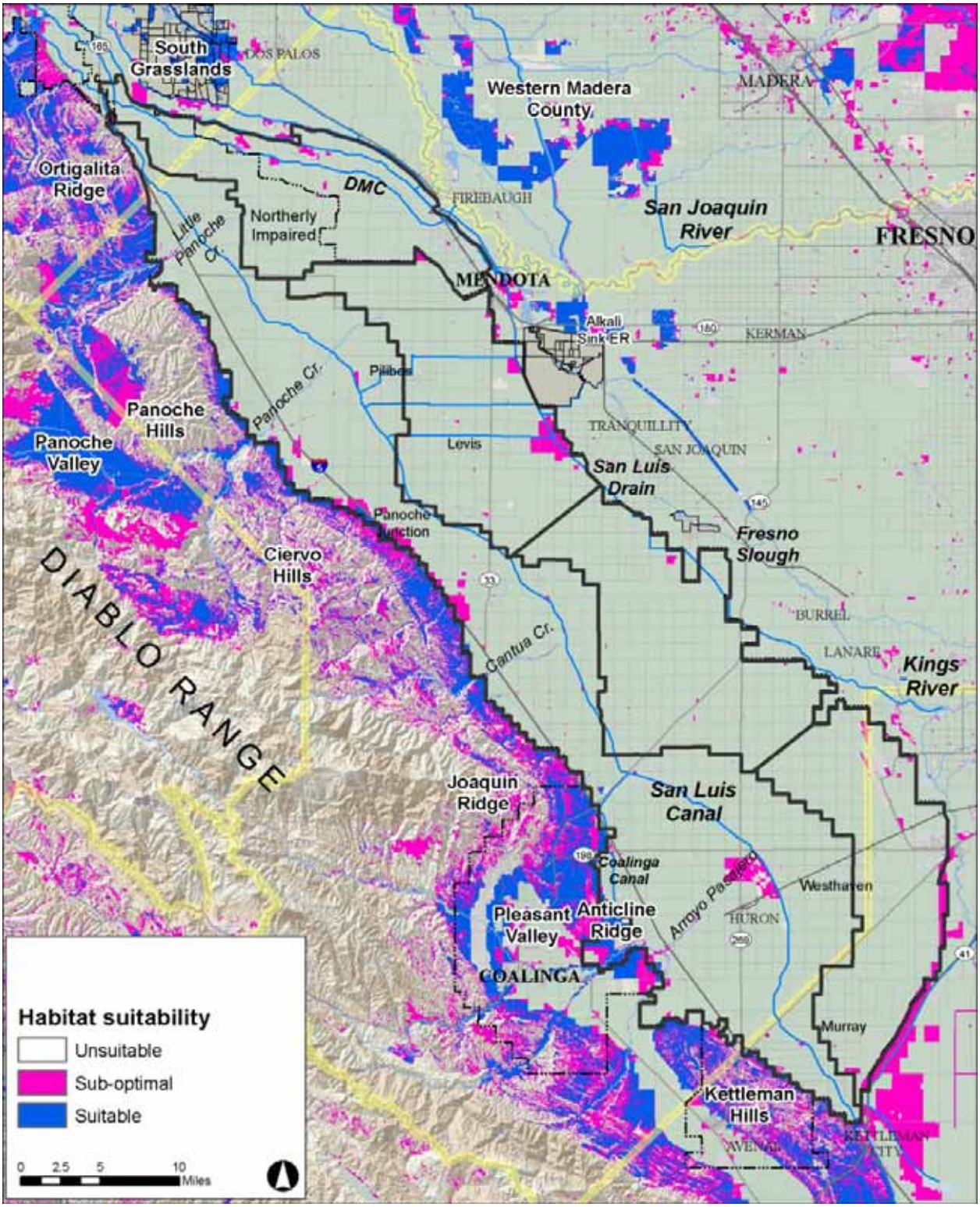

Figure 3. Estimated habitat suitability under current conditions.

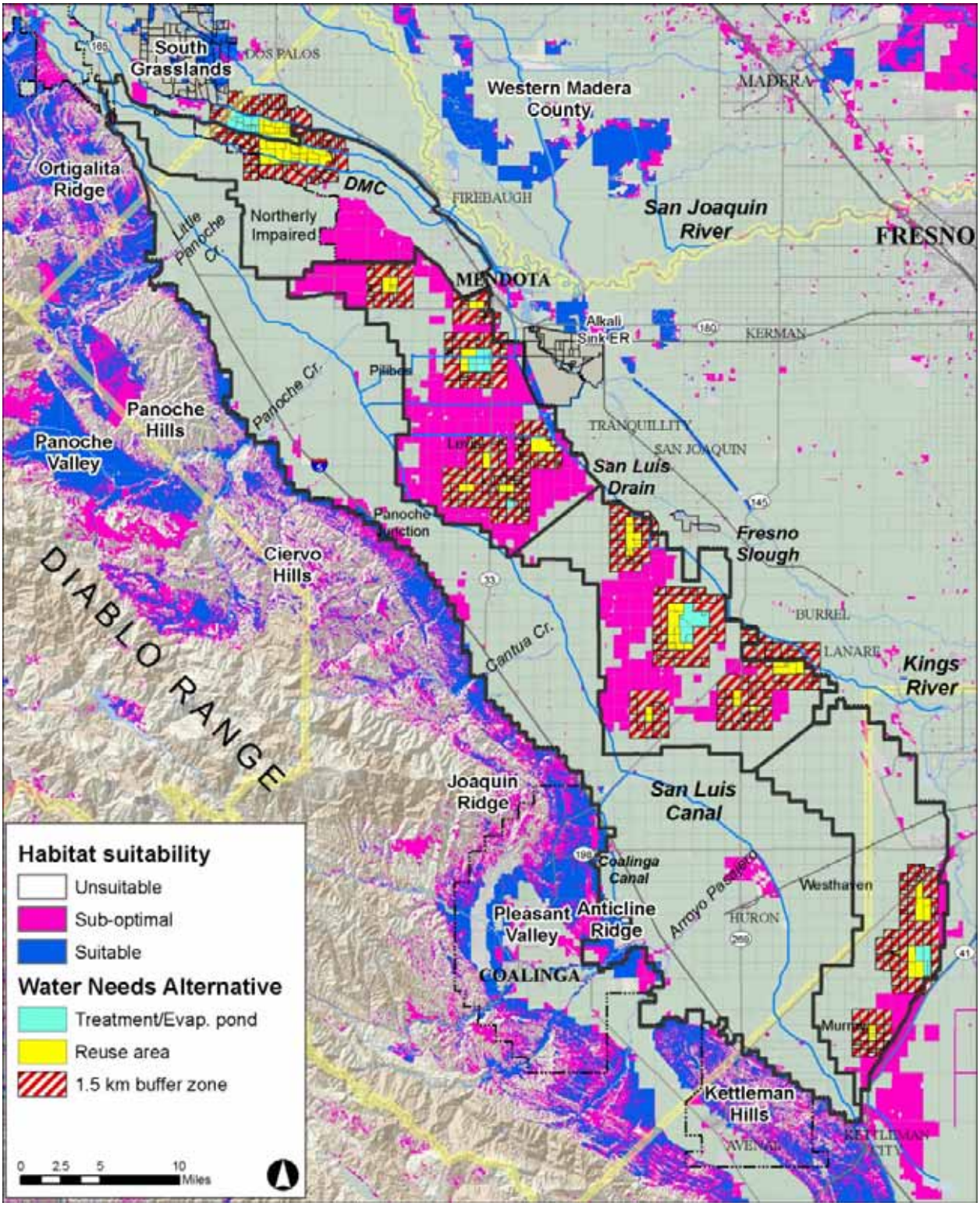

Figure 4. Estimated habitat suitability under the Water Needs Alternative.

HABITAT CONNECTIVITY

Our model predicted that the least cost corridor is a 50.4 km route from the Panoche Valley, south along the foothills to an area near Panoche Junction and northeast through the Westlands North Drainage Impaired Lands in the area of Levis (Figure 5). Under current conditions, the calculated value of the least cost corridor values divided by the length of the least cost path (LCC/LCP) is 20.1. We estimate the LCC/LCP value would lower to 14.6 (72% of current) under conditions of the Water Needs Alternative (Table 2, Figure 6). By comparison, we estimate that a corridor in an area with optimal habitat (between Buena Vista Valley and Lokern, western Kern County) would have an LCC/LCP value of 6.5 and the LCC/LCP value of a corridor between Pleasant Valley and Panoche Valley would have a value of 11.5 (Table 2).

Table 2. Comparison of corridor length (least cost path) and cost per distance (least cost corridor value / corridor length) between an optimal corridor, a corridor between Panoche Valley and Pleasant Valley, and though the San Luis Unit under both current conditions and estimated conditions under the Water Needs Alternative.

		LCC/LCP	
Corridor	**Corridor length**	**Current**	**WNA**
Optimal (Buena Vista to Lokern)	40.8 km	6.5	-
Pleasant Valley to Panoche Valley	52.7 km	11.5	-
Panoche Valley or Pleasant Valley to ASER/WMCO[1]	50.4 km	20.1	14.6
Pleasant Valley only to ASER/WMCO	64.8 km	16.9	13.6

[1] Alkali Sink ER/Western Madera County

If the Panoche Valley is removed from the analysis, our model predicts that the least cost corridor from Pleasant Valley is a 64.8 km route that follows the western edge of the unit northwest to the area of Panoche Junction and from there follows a similar route northeast though the area of Levis (Figure 7). We estimate the LCC/LCP value would lower from 16.9 to 13.6 (80% of current) under conditions of the Water Needs Alternative (Table 2, Figure 8).

Although 14.4 km longer, the cost per unit distance (LCC/LCP) of this route is lower than the corridor from Panoche Valley. However, this difference is due to the additional amount of suitable habitat along the route before it enters the Valley floor, lowering the average cost of the route that crosses a comparable amount of unsuitable habitat as a route from the Panoche Valley.

Between the two potential source populations (Pleasant Valley and Panoche Valley), our model predicts that the optimal corridor is a 42.7 km route that follows the western edge of the San Luis Unit (Figure 9). We estimate the cost per distance unit (LCC/LCP) of this corridor as 11.5, 177% of the estimated value (6.5) in an optimal situation (Buena Vista Valley to Lokern, western Kern County, Figure 10).

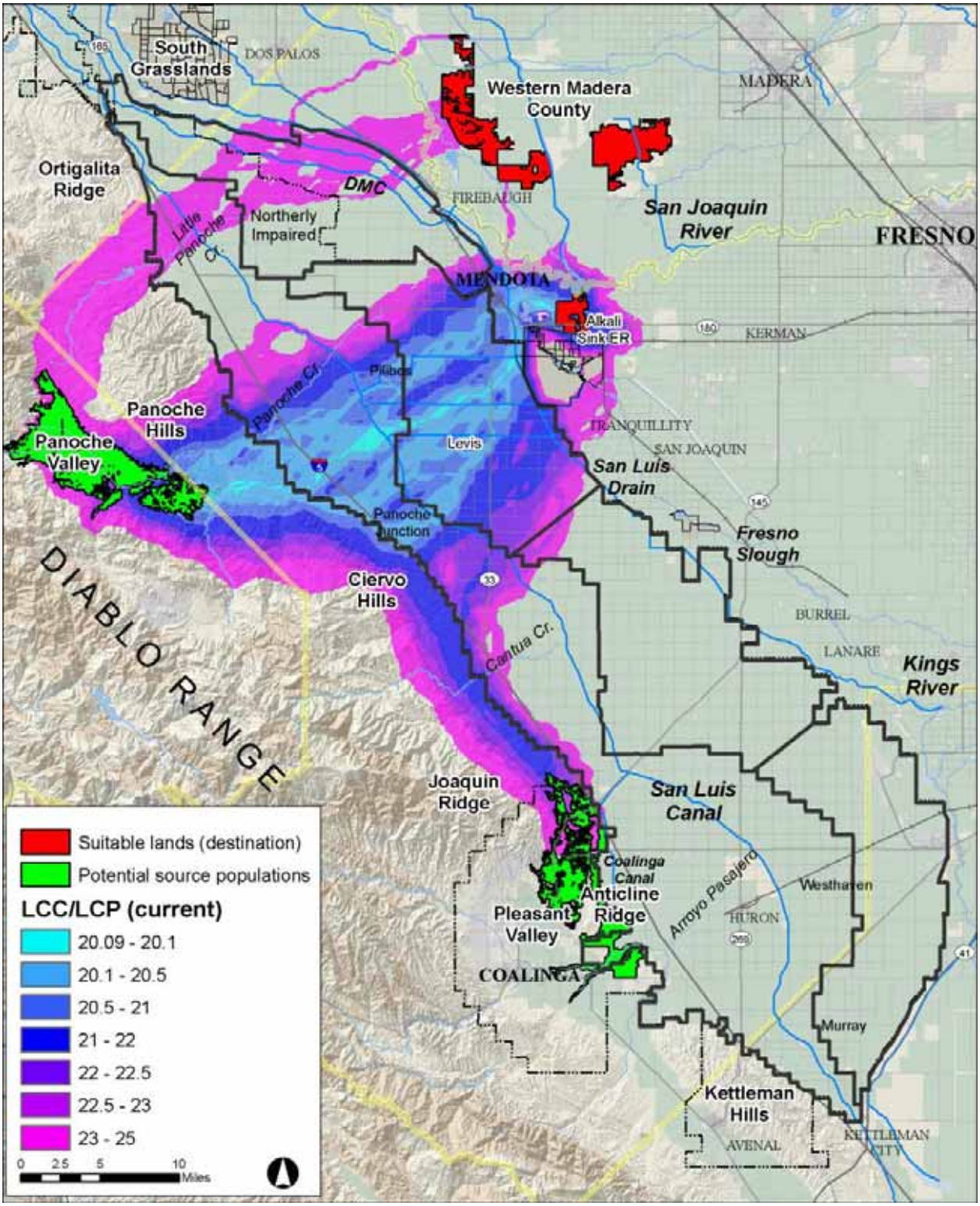

Figure 5. Model result showing a least cost corridor under current conditions of the Water Needs Alternative between either Panoche Valley or Pleasant Valley and isolated blocks of suitable habitat on the Valley floor. Displayed values are the accumulated corridor cost divided by the length of the least cost path.

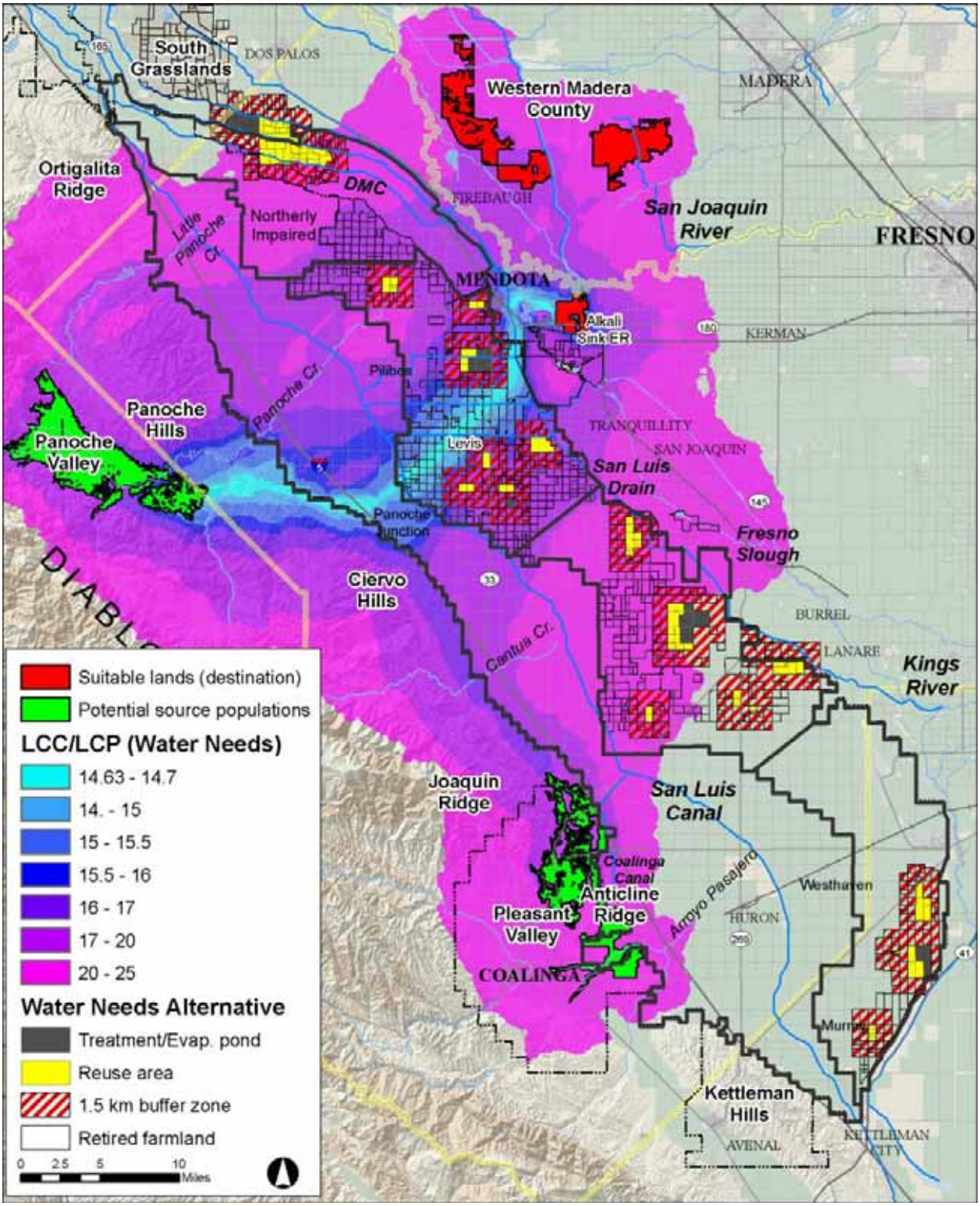

Figure 6. Model result showing a least cost corridor under estimated conditions of the Water Needs Alternative between either Panoche Valley or Pleasant Valley and isolated blocks of suitable habitat on the Valley floor. Displayed values are the accumulated corridor cost divided by the length of the least cost path.

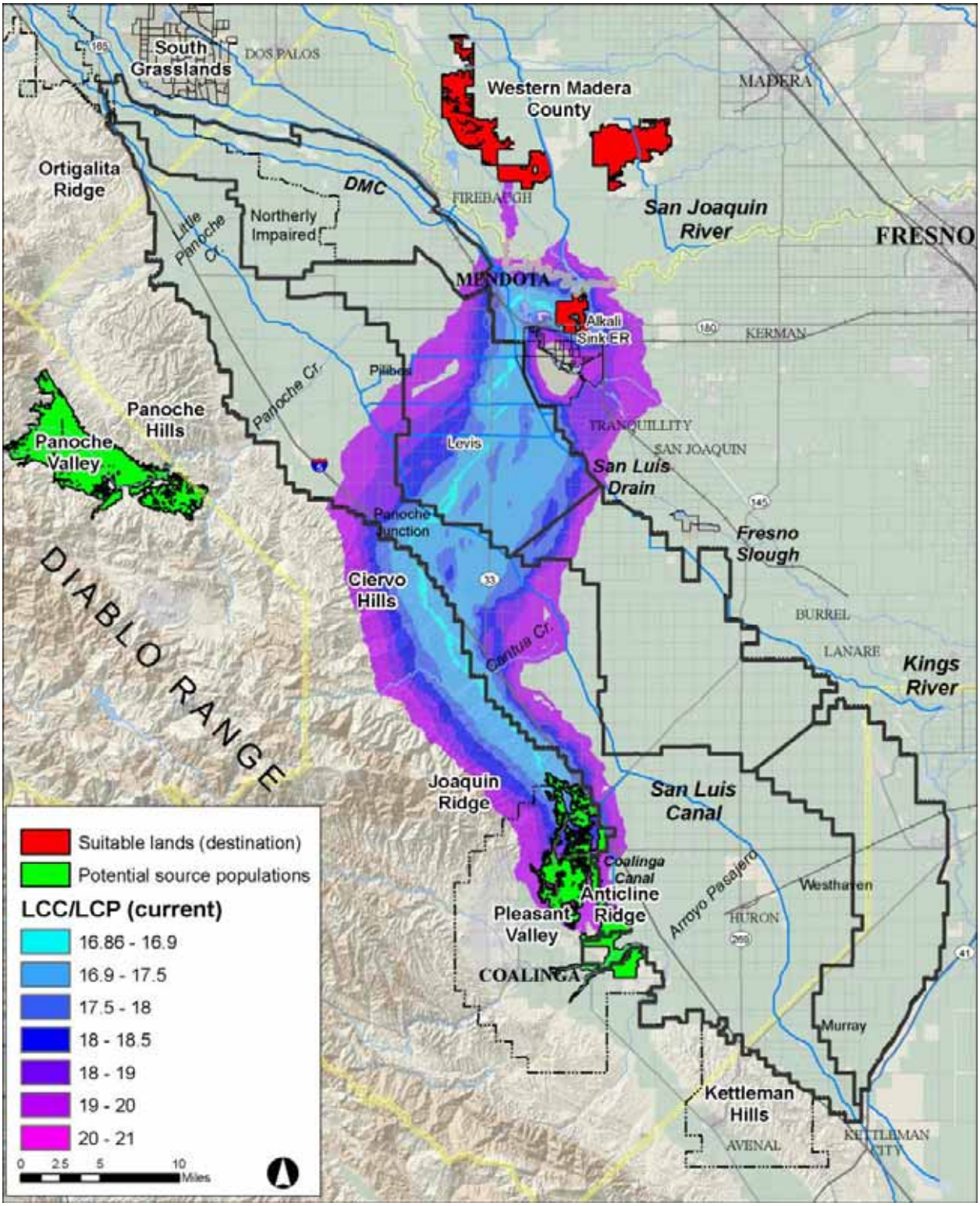

Figure 7. Model result showing a least cost corridor under current conditions between only Pleasant Valley and isolated blocks of suitable habitat on the Valley floor. Displayed values are the accumulated corridor cost divided by the length of the least cost path.

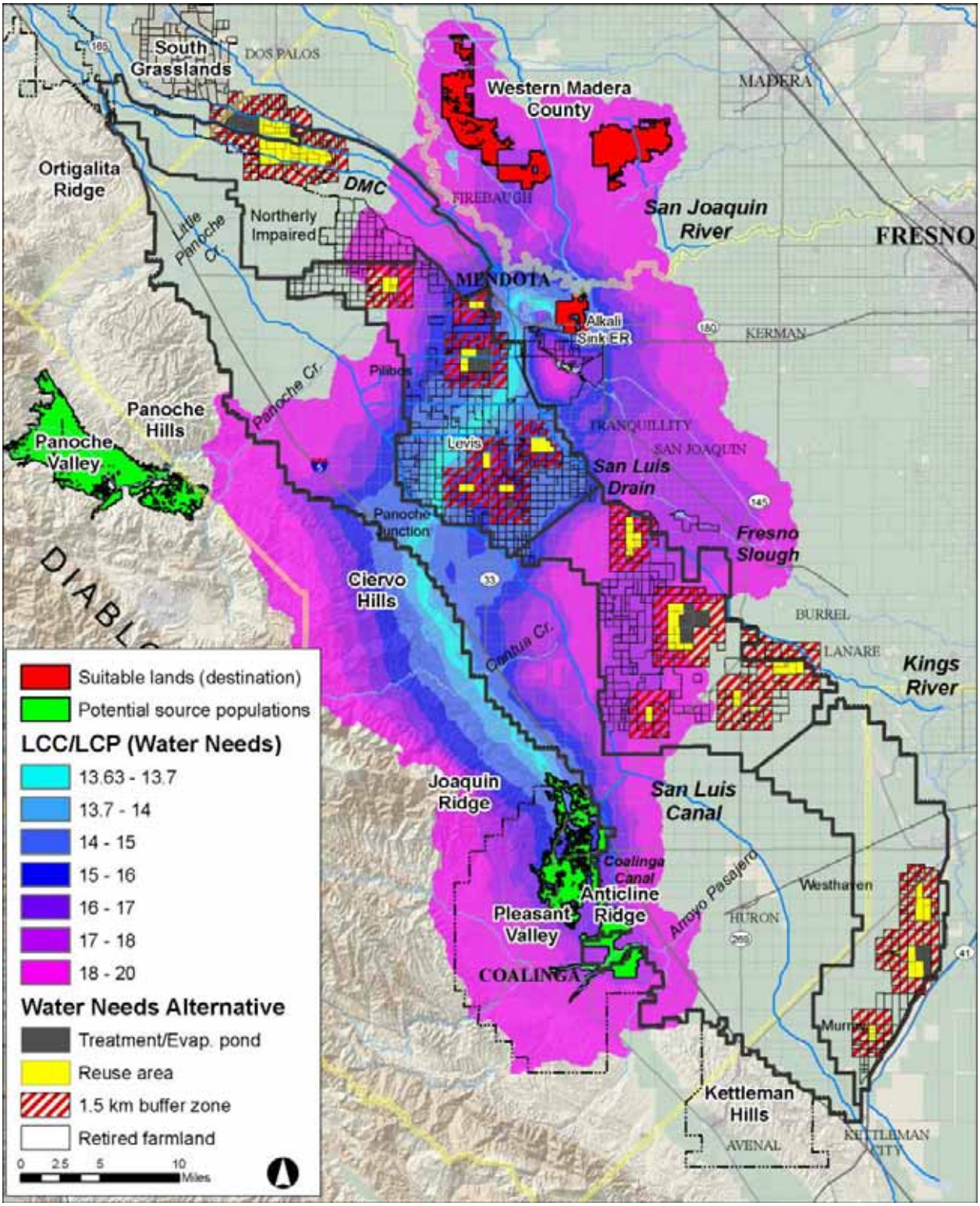

Figure 8. Model result showing a least cost corridor under estimated conditions of the Water Needs Alternative between only Pleasant Valley and isolated blocks of suitable habitat on the Valley floor. Displayed values are the accumulated corridor cost divided by the length of the least cost path.

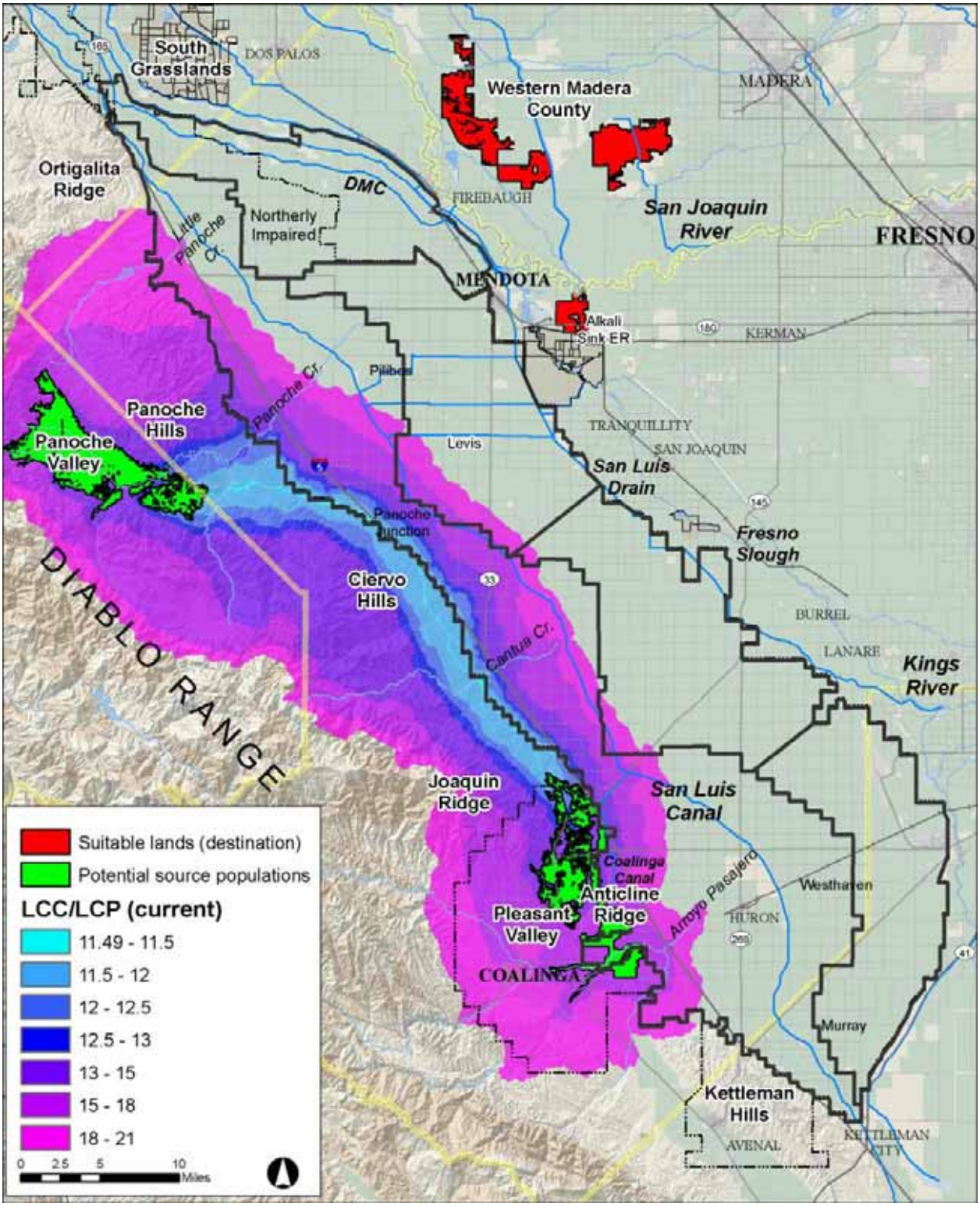

Figure 9. Model result showing a least cost corridor between Pleasant Valley and Panoche Valley. Displayed values are the accumulated corridor cost divided by the length of the least cost path.

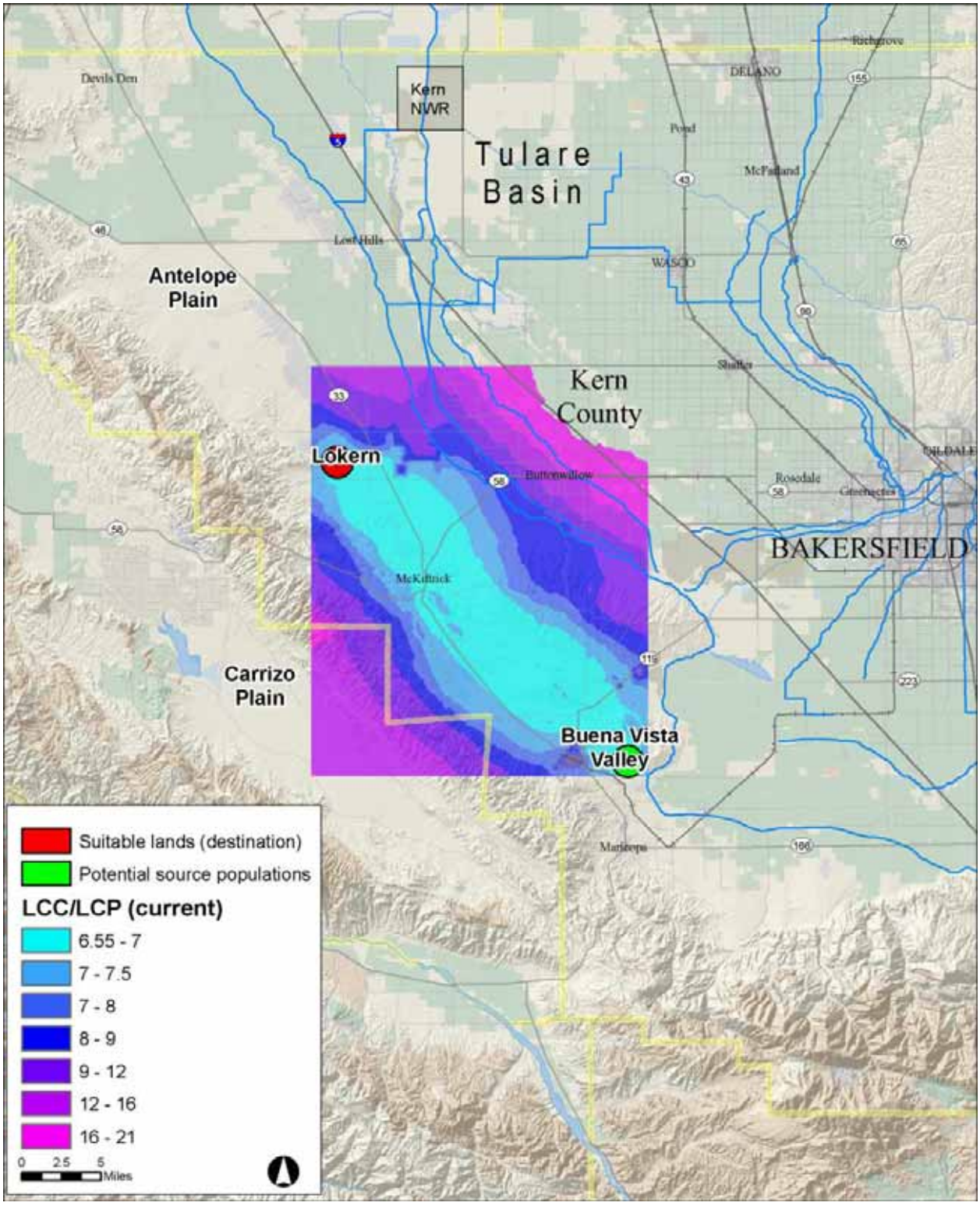

Figure 10. Model result showing a least cost corridor in a in an area of optimal habitat conditions between Buena Vista Valley and Lokern, western Kern County. Displayed values are the accumulated corridor cost divided by the length of the least cost path.

DISCUSSION

HABITAT SUITABILITY

Very little suitable habitat for kit foxes remains in the San Luis Unit. Within the unit boundaries, there are only 5,559 acres (<1%) of suitable habitat and 20,543 acres (2.7%)of sub-optimal habitat (Figure 3, Table 1). Much of the suitable habitat for kit foxes in the SLU is located in the narrow band between the western boundary of the SLU and Interstate 5. The vast majority of the SLU lies east of Interstate 5, and in this area there currently is very little suitable habitat. What suitable habitat there is occurs as very scattered habitat fragments which are all too small in size to support even a single kit fox family group. Based on studies of kit foxes in optimal habitat in the Lokern Natural Area in Kern County, each family group requires approximately 1,500 ac (Nelson et al. 2007). In moderately suitable habitat, considerably more acreage may be needed to support a family group.

Under the preferred alternative for addressing drainage issues in the SLU, large blocks of agricultural lands will be retired from irrigated crop production. Approximately 194,000 ac would ultimately be retired under this alternative (U.S. Bureau of Reclamation 2007*b*). However, not all of these lands would be available for use by kit foxes. Some of these retired lands would be used for water reuse areas and other facilities. Also, an approximately 1-mi wide buffer of non-suitable habitat is proposed around these reuse areas. Thus, of the retired lands, the amount of land that potentially could provide habitat for kit foxes could be as low as 78,126 ac. The majority of the retired lands would be located in the Northerly Impaired, Westlands Impaired North, and Westlands Impaired Central sections of the SLU, with smaller blocks located in the Westlands Impaired South section (Figure 2). These blocks of retired lands appear to be adequate in size to support multiple kit fox family groups. Thus, once retired and colonized by kit foxes, these lands potentially could support a new satellite population.

A significant unknown factor however is the habitat quality on retired lands. Retired agricultural lands have experienced many alterations though a long history of cultivation (Ritter and Lair 2007). These alterations include intermixed soil horizons, soil compaction, loss of microtopography, absence of native plant species, possible absence of nearby native seed sources, chemical (e.g., pesticide, fertilizer) residues, and nearby sources of non-native plant species. As a result, retired agricultural lands may quickly become dominated by dense stands of non-native plants that inhibit or even prevent colonization by native plant species (Ritter and Lair 2007). This could result in a sub-optimal plant community composition for kit foxes or their prey. Equally if not more important, this dense non-native vegetation results in a habitat structure which is less favorable to kit foxes or their prey species. Kit foxes and their preferred prey (particularly kangaroo rats) are adapted to arid habitats with a relatively low, sparse vegetation structure (U.S. Fish and Wildlife Service 1998, Germano et al. 2001, Smith et al. 2006).

Consequently, appropriate restoration and management prescriptions will be necessary to render retired agricultural lands suitable for kit foxes and their prey. Research is being conducted on ecological restoration of retired lands with drainage problems in the SJV. To date, such restoration has proven to be challenging and potentially expensive (e.g., Ritter and Lair 2007). However, continued research eventually may result in the development of successful, cost-

effective restoration prescriptions that provide suitable habitat for kit foxes and their prey. Minimally, retired lands should be managed to produce a favorable vegetation structure. Kit fox prey such as kangaroo rats and ground squirrels can use a wide variety of plants for food, including non-native species (Goldingay et al. 1997, CSUS Endangered Species Recovery Program unpublished data). However, the vegetation structure must be relatively low and sparse, particularly for kangaroo rats. A low, sparse structure also facilitates movement of kit foxes and detection of their predators, especially coyotes. Such a structure should be easily achieved through grazing with either cattle or sheep. Grazing currently is being used as a habitat management tool in other portions of the kit fox range including the Carrizo Plain National Monument and the Lokern Natural Area. Mowing and burning also reduce vegetative structure, but have associated risks and restrictions that may make them less attractive as habitat management tools in the SJV.

Such management prescriptions might require some administrative changes prior to implementation. For example, current management terms and conditions adopted by the Westlands Water District for retired lands prohibit simple grazing as an acceptable land use, requiring periodic disking instead, presumably to control weed growth (Westlands Water District 2005). Such disking would severely inhibit the establishment of rodent burrows, particularly for kangaroo rats, the preferred prey for kit foxes. This disking also would inhibit or even preclude den establishment by kit foxes, which in turn would preclude successful colonization by kit foxes. Disking also could collapse occupied dens resulting in kit fox mortalities. Thus, current policies regarding land management need to be revised if a goal of land retirement is the eventual establishment of a kit fox population. Otherwise, retired lands may provide little or no suitable habitat for kit foxes. Furthermore, based on modeling results, some parcels currently classified as potential habitat would be converted to reuse or other facilities. Thus, in the absence of appropriate habitat management, there actually could be a net loss of at least 3,199 ac of kit fox habitat in the SLU.

Even if vegetation structure is favorable and prey abundance is adequate for foxes, lack of cover likely will be a significant issue. Cover for kit foxes consists of dens. Kit foxes are obligate den users (McGrew 1979). Kit foxes use dens virtually every single day of the year for avoiding predators, avoiding temperature extremes, daytime resting, conserving moisture, and rearing young. Kit foxes establish multiple dens within their home ranges and use an average of 11 different dens each year (range 1-16; Koopman et al. 1998). Dens are particularly important for avoiding predation by coyotes. Few or no adequate dens will be available for kit foxes on retired lands. Until dens are sufficiently abundant on these lands, kit foxes reaching retired lands may be subject to high predation rates such that population establishment is precluded. Thus, the installation of artificial dens should be considered. Both subterranean chambered dens and surface escape dens (Appendix B) should be installed throughout retired lands at a rate of at least 8 per square mile. Furthermore, due to the perched water table in many locations, at least some of these artificial dens should be installed in earthen mounds to prevent flooding of dens. This will significantly improve habitat suitability for kit foxes on retired lands.

HABITAT CONNECTIVITY

For the SLU, there are 2 important goals regarding connectivity. The first concerns establishing connectivity between areas with existing kit fox populations and retired agricultural lands within the SLU. The second concerns establishing connectivity between habitat blocks with the SLU.

Currently, kit foxes in the vicinity of the SLU primarily occur on natural lands with gentle relief west of Interstate 5. In particular, kit fox populations appear to persist in the Ciervo-Panoche area (particularly Panoche Valley) and the Coalinga-Pleasant Valley area (U.S. Fish and Wildlife Service 1998). These areas likely would serve as "source" areas for foxes. Accordingly, corridors from these source areas to blocks of retired agricultural lands in the SLU would significantly facilitate colonization of these lands.

Concomitantly, connectivity should be established and maintained between blocks of retired lands within the SLU. This will facilitate colonization of blocks further from source populations as well as genetic and demographic exchange between blocks. Also, given that the blocks likely will not be of sufficient size to independently support viable populations, occasional local extinctions may occur and inter-block connectivity will facilitate rapid recolonization.

Consideration also should be given to developing corridors to natural lands east of the SLU. Such lands include the Alkali Sink Ecological Reserve, Kerman Ecological Reserve, Mendota Wildlife Area, and natural lands along the San Joaquin River into Madera and Merced Counties. Creating connectivity between these areas and natural lands on the west side of the SJV is an identified recovery task (see "Pertinent Recovery Plan Tasks" below).

The potential efficacy of corridors increases with width and continuity. The wider the corridor and the more continuous the habitat (i.e., not fragmented or interrupted), the more likely the corridors are to be found and used by kit foxes. The feasibility of establishing such corridors will depend upon such factors as land retirement patterns and the availability of willing land sellers within the designated corridors. At a minimum, 10-ac parcels of suitable habitat spaced at 0.25 to 0.5-m intervals in a "stepping stone" pattern is likely necessary to provide foxes a reasonable probability of successfully reaching retired lands. As with the blocks of retired lands, managing corridor lands to create a suitable vegetative structure and installing artificial dens could significantly increase the probability of use by kit foxes.

Under current habitat conditions, corridors into the SLU and on to suitable habitat east of the unit are relatively low in quality based on modeling results (Table 2, Figure 5). The corridors that would provide the least risk for kit foxes would primarily originate in the Ciervo-Panoche region and traverse the Northerly Impaired and Westlands Impaired North sections of the SLU. Under the preferred alternative, the corridor through the Northerly Impaired section likely would be blocked due to the presence of water reuse facilities. However, modeling results generally indicated that the retirement of lands under the preferred alternative might significantly enhance the ability of kit foxes to move into as well as across the SLU (Table 2, Figure 6). Furthermore, such land retirement could result in foxes being able to access the unit from the Pleasant Valley-Coalinga area as well as the Ciervo-Panoche region. An important assumption for this scenario is that lands are not only retired, but also are managed in a manner that increases suitability for kit foxes. Simply retiring agricultural lands without appropriate management will do little to improve habitat suitability or movement potential for kit foxes.

Although retirement of agricultural lands within the SLU may create opportunities for the development of corridors into and within the unit, continuing conversion of suitable habitat to agricultural uses continues to threaten critical kit fox corridors on the western edge of the unit. Connectivity along the western edge of the SJV is considered critical to kit fox recovery (see "Pertinent Recovery Plan Tasks" below). In some locations, suitable habitat along this western edge has been reduced to <0.5 mi in width by new cultivation. This is particularly true in the areas where the Little Panoche Creek, Panoche Creek, and Cantua Creek intersect I-5.

Conversion of some of these croplands to permanent crops such as orchards may improve permeability somewhat for kit foxes, but also increase the likelihood that these lands will stay in agricultural production. Maintenance of this movement corridor needs to be addressed in any regional kit fox conservation strategy. The importance of conserving this corridor also was reflected in modeling results, which suggest that foxes from the Pleasant Valley-Coalinga area likely would access the SLU by first traveling 20-25 miles north along the western edge of the unit and then entering the unit (Figure 8). Thus, this western edge corridor should significantly enhance the probability and rate of colonization of retired lands by foxes by facilitating access from two existing kit fox population centers. This corridor also is essential for maintaining connectivity between the two source populations.

PERTINENT RECOVERY PLAN TASKS

The *Recovery Plan for Upland Species of the San Joaquin Valley* (U.S. Fish and Wildlife Service 1998) stresses the importance of conserving habitat for kit foxes. In particular, habitat protection is critical in remaining population areas and connectivity needs to be maintained between these areas in order to maintain demographic and genetic exchange. Many of the remaining kit fox populations, including the 3 identified "core areas" (i.e., Carrizo Plain, western Kern County, and Ciervo-Panoche Natural Area), are located on the western edge of the SJV. The recovery plan calls for maintaining a corridor along this western edge of the SJV in order to maintain connectivity between these populations.

The Recovery Plan (p. 134) also discusses the potential contribution of retired agricultural lands to kit fox conservation and recovery. Such lands can provide habitat for kit foxes and also can facilitate movements by kit foxes between occupied habitat areas.

The implementation of the preferred drainage strategy could contribute to kit fox conservation and recovery by addressing the following recovery tasks identified in the Recovery Plan:

- Task 1.2.6 Coordinate retirement of farmlands with drainage problems with recovery needs of featured species.
- Task 5.1.1 Establish linkages between in western Fresno County between the Monocline Ridge-Tumey Hills-Panoche Hills area and Mendota Wildlife Area and western Madera County.
- Task 5.3 Maintain linkages of natural lands around the fringe of the Valley and elsewhere for San Joaquin kit fox and other listed and sensitive species.
- Task 5.3.4 Western Valley edge, Santa Nella to Panoche Creek
- Task 5.3.5 Western Valley edge, Panoche Creek to Ciervo Wash
- Task 5.3.6 Western Valley edge, Ciervo Wash to Coalinga
- Task 5.3.7 Western Valley edge, Coalinga to McKittrick

In addition to identifying recovery strategies and specific tasks, the Recovery Plan also provides detailed recommendations for the retirement of farmland with drainage problems relative to endangered species recovery. This information is presented in Appendix F on the recovery plan (pp. 306-308). With regards to recovery of endangered species, some pertinent recommendations include:

- Retiring lands in blocks, as opposed to scattered parcels, with blocks ideally being at least 5,000-6,000 acres in size.
- Connecting such blocks to natural lands on the western edge of the valley via continuous undeveloped land or other natural movement corridors.
- Installing artificial dens to provide cover for foxes.
- Restoring retired lands in a manner that provides suitable habitat for kit foxes and their prey.
- Providing incidental take coverage to adjacent landowners, possibly through Safe Harbor Agreements.

Implementation of these recommendations in combination with appropriate habitat management prescriptions could enhance suitability of habitat for kit foxes on retired lands, increase the effectiveness of movement corridors, facilitate fox movements to and from areas where they are very rare today (e.g., western Madera Co.), facilitate colonization of retired lands, and increase the potential for establishing viable kit fox populations on retired lands in the SLU.

INFORMATION NEEDS

1. Regional status of kit foxes

The regional status of kit fox populations in the vicinity of the SLU is not well known. Based on past and current survey efforts (e.g., Smith et al. 2006, CSUS ESRP unpublished data), kit foxes appear to be consistently present in the Panoche Valley-Silver Creek area, although the overall size and density of the kit fox population in this area are unknown. Virtually no information is available on kit fox presence and abundance from this area south to the Kettleman Hills. Surveys should be conducted in the region to assess the status of kit foxes. The locations and densities of any kit fox populations along the western edge of the SLU will significantly affect the colonization of retired lands within the unit.

2. Ecosystem restoration strategies

Strategies for restoring terrestrial ecosystems in the SJV are poorly developed. Some research efforts have been conducted to identify appropriate prescriptions, but most have met with mixed success (e.g., Hinshaw et al. 1999, Ritter and Lair 2007). Further research and testing is needed to identify successful restoration approaches, particularly those that will result in habitat conditions suitable for kit foxes and other sensitive species. Re-establishment of fully intact and functional native communities is the ideal goal of restoration efforts, but efforts that simply result in a vegetative composition and structure that is suitable for kit foxes and their prey will also be valuable.

3. Habitat management strategies

As discussed in this report, habitat management very likely will be necessary to render retired lands suitable for kit foxes, and even natural lands might benefit from active management. Effective habitat management prescriptions need to be identified, particularly those that can

produce a vegetation structure favorable for kit foxes and their prey. The most economically feasible as well as the most effective will likely will involve grazing with livestock. Factors that need to be evaluated include type of livestock, timing of grazing, grazing intensity, and effects of infrastructure (e.g., stock tanks, access roads, corrals, etc.). Developing effective habitat management prescriptions will increase the potential for colonization of retired lands by kit fox and prey populations, as well as increase the long-term viability of such populations.

4. Prey and competitor response to land retirement

Two important factors that will significantly influence the colonization of retired lands by kit foxes are the response of prey and competitor populations to land retirement. Patterns and rates of colonization by various prey species should be evaluated, and perhaps even experimentally manipulated to assess the feasibility of prey base enhancement. Prey abundance needs to achieve sufficient levels to support kit foxes before foxes can successfully colonize retired lands. Similarly, competitor response should be evaluated on retired lands. Competitors such as coyotes and red foxes are highly adaptable and successful in anthropogenically-altered landscapes. These species could quickly become abundant on retired lands, which could inhibit colonization by kit foxes. Thus, the status and dynamics of prey and competitor species on retired lands needs to be monitored and studied.

5. Outreach

Retired lands are expected to provide habitat for and be colonized by kit foxes. Adjacent landowners may oppose or resist such colonization out of fear that kit foxes will use adjacent lands and potentially constitute a liability. Such resistance and opposition could inhibit the establishment of kit fox populations on retired lands. Outreach efforts would be extremely helpful by providing information, increasing awareness, and fostering positive relationships with landowners. An on-going, proactive outreach program should be developed and implemented in the SLU.

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APPENDIX A. NATURAL AND AGRICULTURAL LAND VALUES FOR SAN JOAQUIN KIT FOX

Adapted from:

Cypher, B.L. 2006. *Kit Fox Conservation in the San Luis Drainage Study Unit.* Unpublished report to the U.S. Bureau of Reclamation South-Central California Area Office. California State University, Stanislaus, Endangered Species Recovery Program. Fresno, CA.

Natural land values

Kit foxes are an aridland-adapted species. They occur in arid regions, typically deserts, throughout North America (Cypher 2003). Accordingly, in the San Joaquin Valley, optimal habitats for San Joaquin kit foxes generally are those in which conditions are more desert-like. These include arid shrublands and grasslands (U.S. Fish and Wildlife Service 1998). These areas are characterized by sparse or no shrub cover, sparse ground cover with patches of bare ground, short vegetative structure (herbaceous vegetation <18 inches tall), and sandy to sandy-loam soils.

Tall and/or dense vegetation generally is less optimal for foxes (Smith et al. 2005). Such conditions make it difficult for foxes to detect approaching predators or capture prey. Kit foxes also tend to avoid rugged, steep terrain. Predation risk apparently is higher for foxes under such topographic conditions (Warrick and Cypher 1998). In general, flat terrain or slopes under 5% are optimal, slopes of 5-15% are suitable, and slopes greater than 15% are unsuitable. For this reason, the foothills of the Coast Ranges generally are considered to demark the western boundary for suitable kit fox habitat. Finally, kit foxes appear to be strongly linked ecologically to kangaroo rats. Kit foxes are especially well adapted for preying on kangaroo rats, and consequently, kit fox abundance and population stability is highest in areas where kangaroo rats are abundant (U.S. Fish and Wildlife Service 1998, Cypher 2003). Kangaroo rats also are aridland-adapted species, and thus, reach their greatest densities in the San Joaquin Valley in arid habitats.

Following are assessments of relative value for various natural habitats present in the San Joaquin Valley:

Saltbush scrub

This is an aridland habitat generally dominated by saltbush shrubs (*Atriplex* spp.), and with ground cover dominated by non-native Brome grasses (*Bromus* spp.). Kangaroo rats are abundant. This habitat is **optimal** for kit foxes, and kit foxes generally achieve their highest densities in areas with this habitat type (e.g., Lokern Natural Area, Buena Vista Valley, Carrizo Plain, Elkhorn Plain). Although this habitat is favorable for foxes, it should be noted that dense patches of shrubs provide cover for kit fox predators and may be avoided by foxes.

Arid grasslands

This is an aridland habitat with few or no shrubs, and which is dominated by non-native grasses, particularly red brome (*Bromus madritensis rubens*). Vegetation structure is low and patches of bare ground are common. Kangaroo rats are abundant. This habitat is **optimal** for kit foxes. Grazing can further reduce the vegetative structure rendering this habitat even more suitable.

Alkali sink

This habitat occurs in lower regions closer to the Valley center, and thus is subject to soil saturation and seasonal flooding in the winter and spring. It usually is dominated by iodine bush (*Allenrolfea* spp.) or sinkweed (*Suaeda* spp.) shrubs with a patchy, low-structure ground cover. Kangaroo rats can be abundant. This habitat **can be suitable** for kit foxes, particularly if slightly higher topography is available for dens.

Mesic grasslands

This habitat type is more common in the eastern and northern portions of the Valley where precipitation is more abundant. This type tends to have few or no shrubs and is dominated by non-native wild oat grasses (*Avena* spp.). Vegetation structure may be higher than 18 inches and dense, particularly in years with above-average precipitation, and this could result in increased predation risk for kit foxes. Bare ground may be sparse. The rodent community tends to be dominated by California ground squirrels instead of kangaroo rats. This habitat **can be suitable** for kit foxes, particularly if it is moderately to heavily grazed.

Oak woodland savannah

This habitat occurs primarily off the Valley floor up in the Coast Ranges. Oak trees (*Quercus* spp.) tend to form a sparse to moderate canopy, and the herbaceous cover is dominated by non-native wild oats and other grasses. Vegetation structure and density tends to be high with little bare ground. Kangaroo rats are not abundant and California ground squirrels are common. This type probably is **marginally suitabl**e for kit foxes at best, although grazing can improve permeability for kit foxes.

Chaparral

This habitat occurs in higher, more mesic areas in the Coast Ranges. It is characterized by a diverse and dense shrub community. Predation risk is high and kangaroo rats are uncommon. This habitat is **unsuitable** for kit foxes.

Wetlands and riparian forests

These habitats are characterized by wetland and riparian vegetation that can be quite dense. Constant or periodic flooding preclude den establishment and kangaroo rats are less common. These habitats are **unsuitable** for kit foxes.

Agricultural land values

Agricultural lands inherently present challenges for kit foxes. Ground disturbance is frequent (e.g., tilling, maintenance, harvesting), which can destroy dens. Also, most agricultural lands in the Valley are irrigated, which can flood and collapse dens. Agricultural lands also are subject to intensive chemical applications, including fertilizers, pesticides, and defoliants. Use of rodenticides is common in some agricultural environments and is particularly problematic for kit foxes due to the potential for secondary poisoning. Finally, all of the factors above in addition to the relative sterility of most agricultural fields (e.g., weed suppression) result in a lack of prey availability for kit foxes.

Another detrimental attribute of agricultural lands is the presence of coyotes and non-native red foxes. Coyotes are the primary cause of mortality for kit foxes in most areas (Cypher et al. 2003). The threat to kit foxes from red foxes is still being evaluated, but the potential for both interference and exploitative competition is high (Cypher et al. 2001). These highly adaptable species are able to persist in agricultural lands. They are not dependent on dens for cover, they are highly mobile which facilitates avoiding dangers and locating food, and they are highly omnivorous. Also, kit foxes are more vulnerable to predation in agricultural areas due to the relative scarcity of den sites, as described previously. Thus, agricultural lands are generally not suitable for long-term occupation by kit foxes, although lands adjacent to natural habitats may be used for occasional foraging (Warrick et al. submitted).

Most available information on the value of agricultural lands to kit foxes is qualitative in nature, but one quantitative investigation has been conducted (Warrick et al. submitted). Following are assessments of relative value for several types of agricultural lands:

Annual crops

Annual crops (e.g., cotton, tomatoes, alfalfa, carrots): Lands with these crops usually have low to no prey (except possibly alfalfa), and are subject to frequent disturbance, irrigation, and chemical application. Kit foxes do not appear able to permanently occupy these lands, and use primarily appears limited to occasional foraging when these lands are adjacent to natural habitats.

Orchards

(e.g., fruit trees, nut trees): Lands with these crops are not always "sanitized" of all herbaceous vegetation, and therefore sometimes may support some prey (primarily ground squirrels, deer mice, and house mice). Also, the open understory of orchards facilitates predator detection by kit foxes. Kit foxes have been observed to forage in orchards as well as to occasionally spend a day or so resting, usually in man-made structures (e.g., pipes, rubble piles). Orchards are probably relatively permeable for kit foxes, although the risk of an unsuccessful crossing most likely increases with distance.

Vineyards

Lands with these crops are not always "sanitized" of all herbaceous vegetation, and therefore sometimes may support some prey (primarily ground squirrels, mice). Vineyards probably are permeable to kit foxes, but as with orchards, the risk of an unsuccessful crossing most likely increases with distance. Also, the rodent-proof fences erected around some vineyards would severely inhibit entry by kit foxes.

Fallow land values

Some agricultural lands may be fallowed for a season, a year, or multiple years. The value of these lands for kit foxes is highly dependent upon the duration of fallowing and the location of the lands. Lands that are fallowed for only a season likely have little value to foxes. Generally, a season is not sufficient time for a prey base to reestablish. Also, renewed ground disturbance and irrigation at the end of the season likely would result in the destruction of any fox dens created during the fallow period. Lands that are fallowed for 1 or more years could have greater

value to kit foxes. This time period might be sufficient for the reestablishment of some prey and the creation of dens. Lands fallowed for multiple years could even potentially be used by kit foxes to produce and raise young. Kit foxes likely would be forced from these lands when they were returned to agricultural production. Kit foxes would be at risk of injury or death during the reinitiation of agricultural activities if they failed to vacate the property in a timely manner. Foxes that did vacate also would be at greater risk if they were forced into unfamiliar areas.

Fallow lands immediately adjacent to natural lands might be use relatively quickly by kit foxes. In Kern County near Bakersfield, foxes have been observed to utilize agricultural lands within weeks of being fallowed with use increasing as these lands remained fallowed (B. Cypher, personal observation). As the distance between fallow lands and occupied habitat increases, the potential for use by kit foxes decreases. As described above, kit foxes face risks when crossing agricultural lands, and this risk may preclude colonization or use of fallow lands that are not adjacent to occupied habitat.

Value of Retired Agricultural Lands for Kit Foxes

Current value

Most retired lands within the SLDSU probably do not currently support kit fox populations. This conclusion is based on the absence of reports of kit foxes from these areas (e.g., sightings, roadkills, etc.). The absence of kit foxes in these areas is likely a function of 2 main factors: proximity to natural lands with existing fox populations and habitat conditions on the retired lands.

The closest known kit fox populations on natural lands probably are west of I-5 in saltbush scrub and grassland habitats. These populations are at least 5 miles from most retired lands. Although this distance is well within the dispersal potential of kit foxes, intensive agriculture on the intervening lands significantly inhibits the ability of kit foxes to disperse from the natural lands to the retired lands.

Habitat conditions on most retired agricultural lands are suboptimal for kit foxes for a variety of reasons. (1) On many parcels, dense growths of weedy species are present, such as mustards (e.g., *Brassica nigra*, *Sisymbrium irio*), five-hook bassia (*Bassia hyssopifolia)*, and silverscale (*Atriplex argentea*). This dense growth hinders kit fox movements and their ability to detect predators, and also may inhibit preferred prey such as kangaroo rats. (2) Some of these lands also tend to have soil saturation problems as a function of their poor drainage, and this could result in seasonal flooding of fox dens, particularly in the winter and spring. This would make it difficult for foxes to establish cover, which is necessary for avoiding predators. (3) Depending upon how long lands have been retired, a sufficient prey base may not have gotten established to support kit foxes. Colonization by prey species would depend upon habitat conditions and proximity to source populations, and could be further affected by rodenticide use on adjacent lands. (4) Finally, the size and juxtaposition of the retired parcels will affect establishment by kit foxes. Each kit fox family group requires about 1,200 acres, based on studies in optimal habitat. Space requirements could be even higher in suboptimal habitats. If lands are retired in a manner that results in a isolated parcels lacking connectivity, kit foxes may have difficulty getting established.

Future value

The potential value of retired agricultural lands for kit foxes is strongly dependent upon a variety of factors, many of which are introduced above. Drainage impaired lands historically likely were occupied by alkali sink or even wetland communities. Wetland communities are not suitable habitat for kit foxes. Alkali sink communities appear to be suitable, with suitability likely increasing with soil aridity. Although not the optimal habitat for kit foxes, foxes commonly occur in this community type in such places as the Semitropic Ridge area (just south of Kern National Wildlife Refuge in Kern County) and Coles Levee Ecopreserve (western Kern County). Thus, under natural conditions, these areas may not have supported highly dense kit fox populations, and foxes certainly could have difficultly (as described above) reoccupying these highly altered lands.

However, with planning and active management, retired drainage-impaired agricultural lands could have value for kit foxes. Below are potential strategies and actions that could increase the value of retired lands for kit foxes.

Lands should be retired in large blocks, or minimally, retired in a manner that results in connected parcels. As mentioned previously, a kit fox family group requires a minimum of 1,200 acres. Blocked/connected lands totally 6,000 acres might be a prudent goal as this would potentially accommodate 5 kit fox family groups and reduce the risk of local extinction.

Subsequent use of retired parcels would need to be compatible with kit foxes. Compatible would include grazing and low-intensity recreation. Incompatible uses would include planting of crops (either annual or perennial), building dairies or feed lots, drain water disposal, and intensive recreation (e.g., intense OHV use).

Active vegetation management may be required on retired parcels to create a structure more suitable for kit foxes. Possible management prescriptions include grazing, mowing, and burning. Grazing would be particularly preferred due to the low risk of impacts to foxes (versus mowing or burning), and because grazing would generate an economic return which would reduce the net cost of managing the lands.

Enhancements could be implemented on retired lands that might benefit kit foxes. Artificial dens could be installed to provide escape cover, daytime resting cover, and structures for rearing young. Den establishment might be particularly important in early colonization phases as very few natural dens will be present for foxes. Another enhancement might include the reestablishment of microtopography, which would create more optimal den sites for foxes and also benefit prey species, particularly kangaroo rats.

If the above strategies and management are implemented, retired lands could provide a significant benefit to kit foxes, and contribute to range-wide recovery by increasing the number of kit fox populations. A significant caveat to the above is that retired lands will need to have connectivity to natural lands to facilitate initial colonization and genetic exchange following colonization (see “Regional Kit Fox Conservation Strategy” below).

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APPENDIX B. ARTIFICIAL DEN DESIGNS

ESCAPE DENS

Designed to provide escape cover for kit foxes. Two different lengths were used to determine whether kit foxes preferred the greater seclusion associated with a longer den.

1. A 10-ft long length of pipe placed on the surface of the ground and covered with several inches of dirt to provide thermal insulation.
2. A 20-ft long length of pipe placed on the surface of the ground and covered with several inches of dirt to provide thermal insulation.

SUBTERRANEAN DENS

Designed to provide escape cover as well as diurnal resting cover for kit foxes. The 2 designs used will determine preference by foxes for 1 versus 2 entrances.

3. A 10-ft length of pipe with one end at the surface and one end buried approximately 3 ft underground. Underground end is open to allow foxes to expand the den and even create new entrances.
4. A 3-ft length of pipe buried approximately 3 ft underground and accessed by 2 5-ft long entrance pipes.

CHAMBERED DENS

Designed to provide escape cover and diurnal resting cover for kit foxes, and also provides a chamber for resting or reproduction. The 2 designs used will determine preference by foxes for 1 versus 2 entrances. Also, 2 different chamber designs were used to determine whether foxes exhibit any preference among designs.

5. A chamber buried approximately 3 ft deep with one 5-ft long entrance pipe.
6. A chamber buried approximately 3 ft deep with two 5-ft long entrance pipes.

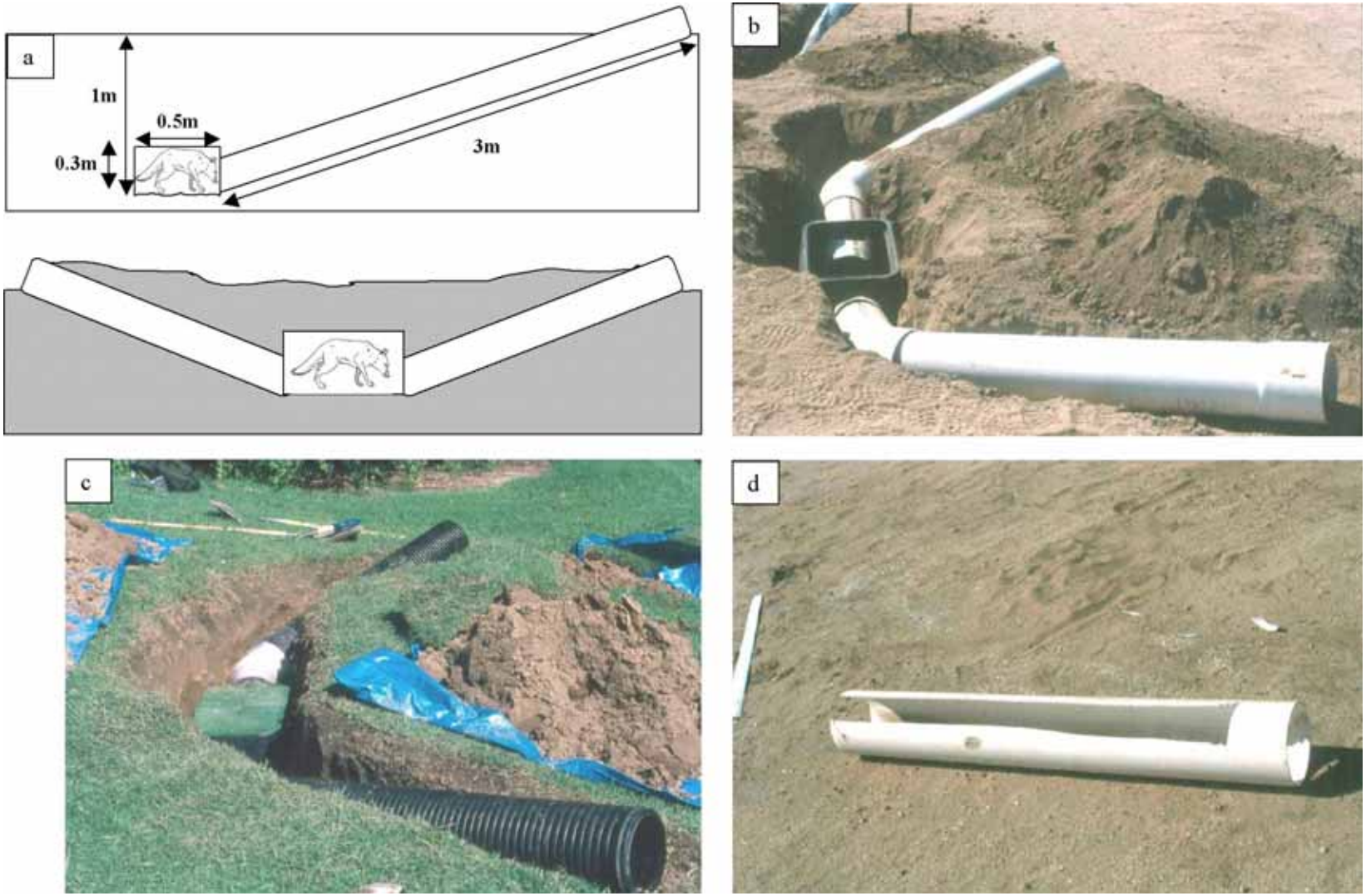

Plate 1. Artificial subterranean dens for San Joaquin kit fox at Bakersfield, CA. a) Artificial den schematic. b) PVC two-entrance chamber den under construction. c) High-density polyethylene two-entrance den. d) PVC tunnel with floor removed longitudinally.

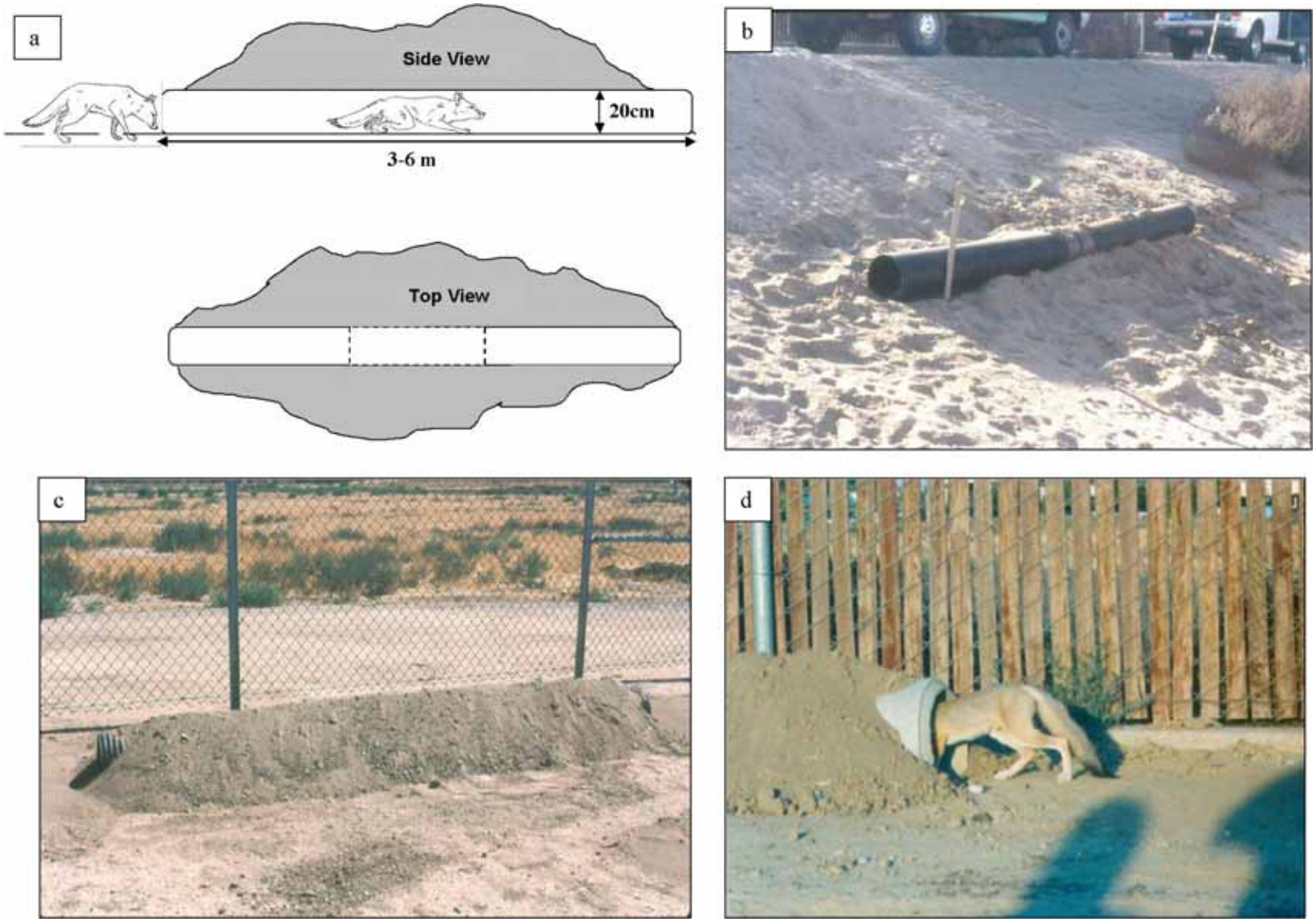

Plate 2. Artificial escape dens for San Joaquin kit fox at Bakersfield, CA. a) Escape den schematic. b) High-density polyethylene escape den under construction. c) Completed den. d) Kit fox entering escape den.

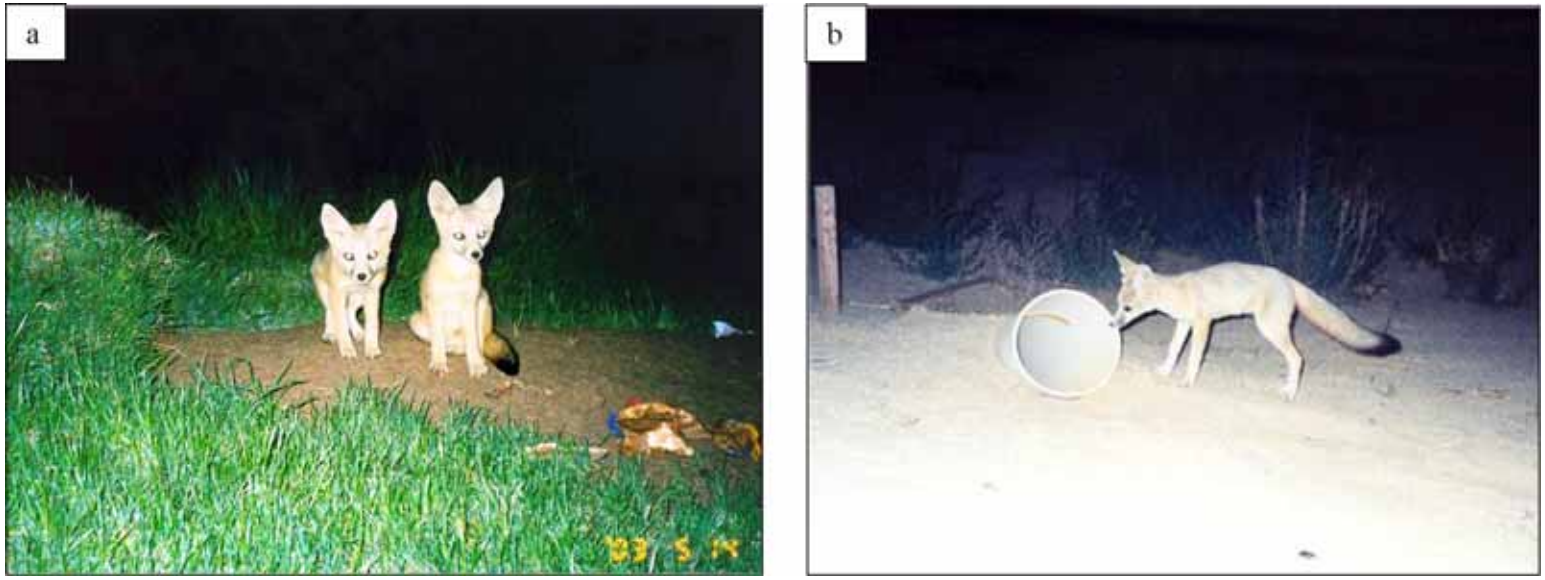

Plate 3. Kit fox pups at artificial subterranean dens at a golf course (a) and drainage basin (b) in Bakersfield, CA.