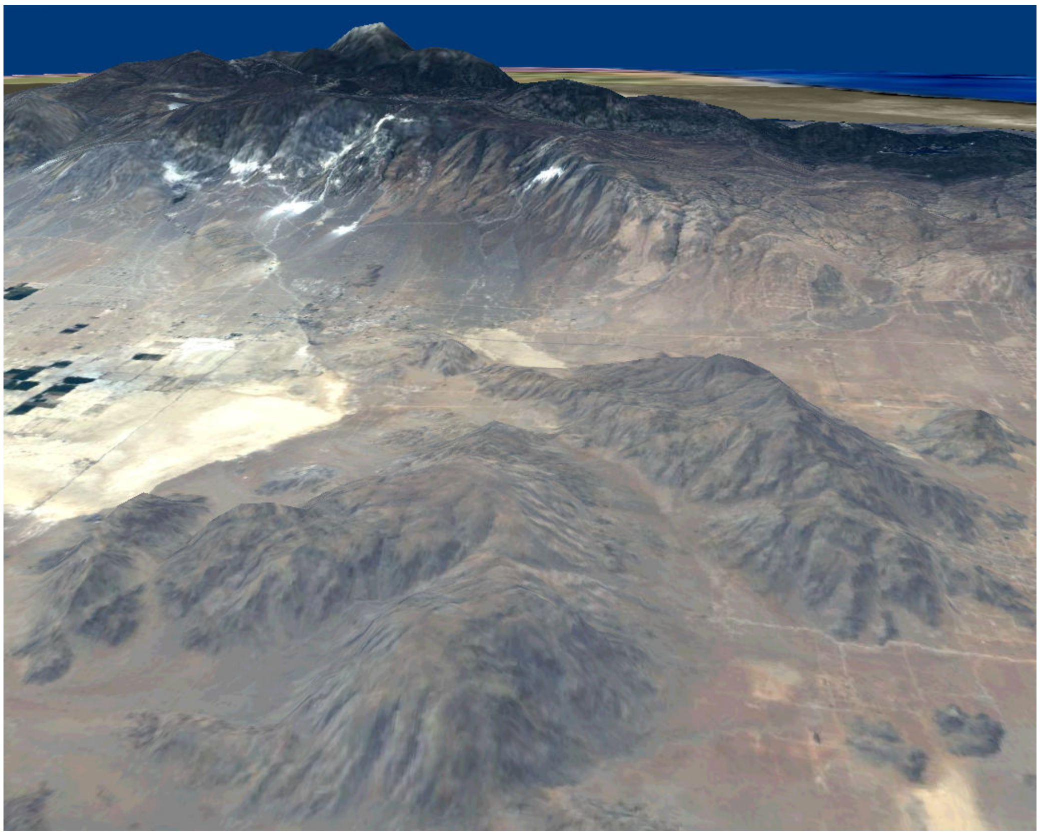
South Coast Missing Linkages Project:

A Linkage Design for the San Bernardino – Granite Connection



Prepared by:

Kristeen Penrod
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Dr. Paul Beier
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SOUTH COAST WILDLANDS

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December 2005

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Produced by South Coast Wildlands: Our mission is to protect, connect and restore the rich natural heritage of the South Coast Ecoregion through the establishment of a system of connected wildlands.

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Table of Contents

Linkage Design

Appendices (Enclosed CD)

List of Tables

List of Figures

Workshop Speakers: Greg Ballmer, Tri-County Conservation League; Chris Brown, USGS Biological Resources Division; Paul Beier, Northern Arizona University; Geary Hund, formerly with California State Parks; Tim Krantz, University of Redlands; Bill LaHaye, University of Minnesota, St. Paul; Claudia Luke, San Diego State University Field Stations Program; Chet McGaugh & John Green, AMEC; Tom Scott, University of California, Riverside; and Wayne Spencer, Conservation Biology Institute.

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Executive Summary

Habitat loss and fragmentation are the leading threats to biodiversity, both globally and in southern California. Efforts to combat these threats must focus on conserving well-connected networks of large wildland areas where natural ecological and evolutionary processes can continue operating over large spatial and temporal scales—such as top-down regulation by large predators, and natural patterns of gene flow, pollination, dispersal, energy flow, nutrient cycling, inter-specific competition, and mutualism. Adequate landscape connections will thereby allow these ecosystems to respond appropriately to natural and unnatural environmental perturbations, such as fire, flood, climate change, and invasions by alien species.

The tension between fragmentation and conservation is particularly acute in California, because our state is one of the 25 most important hotspots of biological diversity on Earth. And nowhere is the threat to connectivity more severe than in southern California—our nation's largest urban area, and still one of its fastest urbanizing areas. But despite a half-century of rapid habitat conversion, southern California retains some large and valuable wildlands, and opportunities remain to conserve and restore a functional wildland network here.

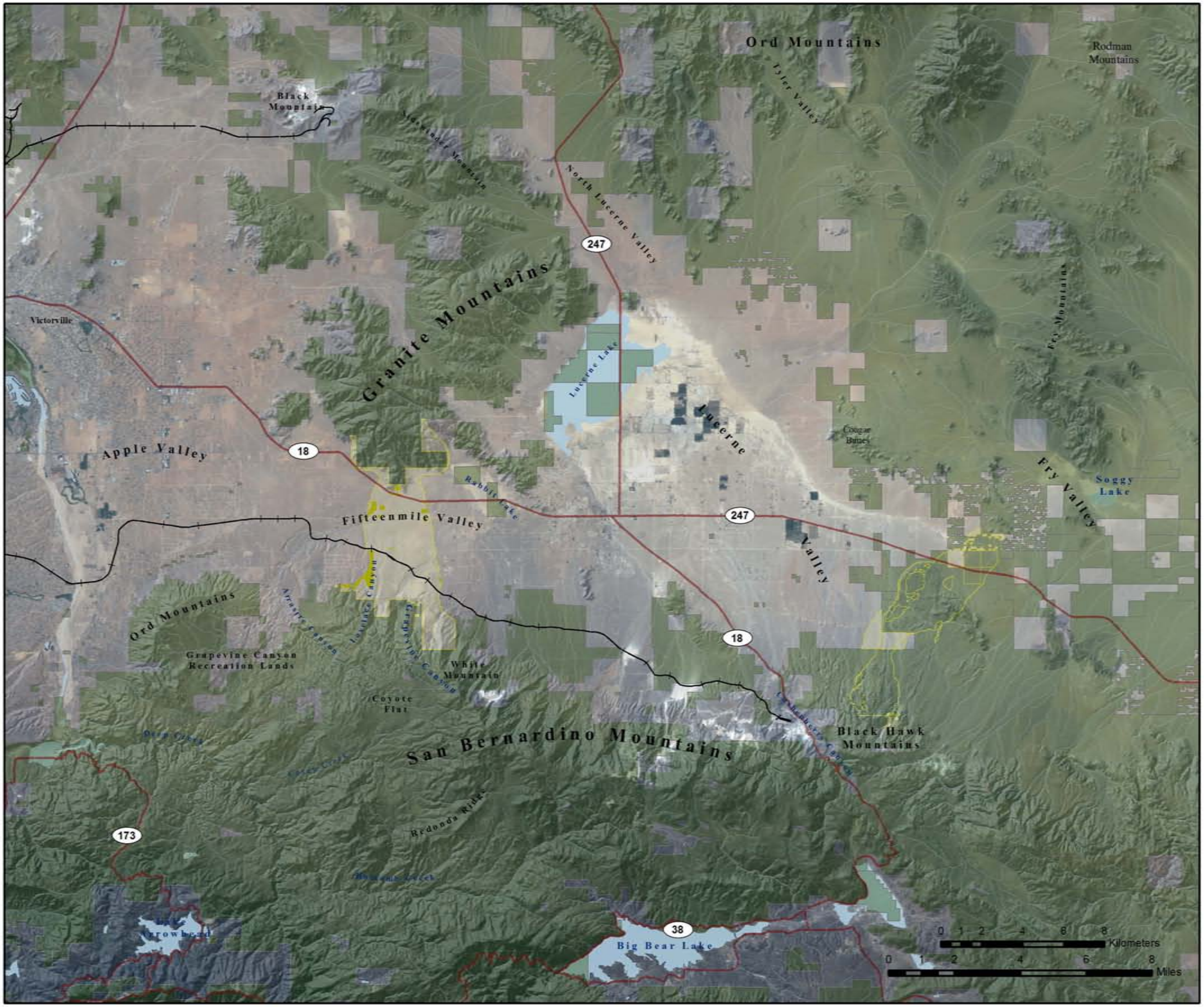
Although embedded in one of the world's largest metropolitan areas, southern California's archipelago of conserved wildlands is fundamentally one interconnected ecological system, and the goal of South Coast Missing Linkages is to keep it so. South Coast Missing Linkages is a collaborative effort among a dozen governmental and non-governmental organizations. Our aim is to develop Linkage Designs for 15 major landscape linkages to ensure a functioning wildland network for the South Coast Ecoregion, along with connections to neighboring ecoregions. The San Bernardino-Granite Connection is situated in an ecological transition zone between the South Coast and Mohave ecoregions; it is a critical landscape connection to restore and protect.

On August 7, 2002, 86 participants representing over 44 agencies, academic institutions, land managers, land planners, conservation organizations, and community groups met to establish biological foundations for planning landscape linkages in the San Bernardino-Granite Connection. They identified 14 focal species that are sensitive to habitat loss and fragmentation here, including 1 plant, 4 insects, 1 reptile, 2 birds and 6 mammals. These focal species cover a broad range of habitat and movement requirements: some are widespread but require huge tracts of land to support viable populations (e.g., bighorn sheep, badger); others are species with very limited spatial requirements (e.g., desert woodrat). Many are habitat specialists (e.g., rock wren) and others require specific configurations of habitat elements (e.g. greenhairstreak butterfly that requires hilltopping habitat). Together, these species cover a wide array of habitats and movement needs in the region, so that planning adequate linkages for them is expected to cover connectivity needs for the ecosystems they represent.

To identify potential routes between existing protected areas we conducted landscape permeability analyses for 3 focal species for which appropriate data were available. Permeability analyses model the relative cost for a species to move between protected core habitat or population areas. We defined a least-cost corridor—or best potential route—for each species, and then combined these into a Least Cost Union covering all 3 species. We then analyzed the size and configuration of suitable habitat patches within this Least Cost Union for all focal species to verify that the final Linkage Design would suit the live-in or move-through habitat needs of all. Where the Least Cost Union omitted areas essential to the needs of a particular species, we expanded the Linkage Design to accommodate that species' particular requirements to produce a final Linkage Design (Figure ES-1). We also visited priority areas in the field to identify and evaluate barriers to movement for our focal species. In this plan we suggest restoration strategies to mitigate those barriers, with special emphasis on opportunities to reduce the adverse effects of State Highways 18 and 247.

ES-1. Linkage Design

Linkage Design
Stewardship Zone
Protected Lands
Hydrography
Roads
Railroads



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The ecological, educational, recreational, and spiritual values of protected wildlands in the South Coast Ecoregion are immense. Our Linkage Design for the San Bernardino-Granite Connection represents an opportunity to protect a truly functional landscape-level connection. The cost of implementing this vision will be substantial—but the cost is small compared with the benefits. If implemented, our plan would not only permit movement of individuals and genes between the San Bernardino Mountains and the Granite, Ord, and Rodman Mountains, but should also conserve large-scale ecosystem processes that are essential to the continued integrity of existing conservation investments throughout the region. We hope that our biologically based and repeatable procedure will be applied in other parts of California and elsewhere to ensure continued ecosystem integrity in perpetuity.

Introduction

Nature Needs Room to Roam

Movement is essential to wildlife survival, whether it be the day-to-day movements of individuals seeking food, shelter, or mates, dispersal of offspring (e.g., seeds, pollen, fledglings) to new home areas, or migration of organisms to avoid seasonally unfavorable conditions (Forman 1995). Movements can lead to recolonization of unoccupied habitat after environmental disturbances, the healthy mixing of genes among populations, and the ability of organisms to respond or adapt to environmental stressors. Movements in natural environments lead to complex mosaics of ecological and genetic interactions at various spatial and temporal scales.

In environments fragmented by human development, disruption of movement patterns can alter essential ecosystem functions, such as top-down regulation by large predators, gene flow, pollination and seed-dispersal, competitive or mutualistic relationships among species, resistance to invasion by alien species, energy flow, and nutrient cycling. Without the ability to move among and within natural habitats, species become more susceptible to fire, flood, disease and other environmental disturbances and show greater rates of local extinction (Soulé and Terborgh 1999). The principles of island biogeography (MacArthur and Wilson 1967), models of demographic stochasticity (Shaffer 1981, Soulé 1987), inbreeding depression (Schonewald-Cox 1983; Mills and Smouse 1994), and metapopulation theory (Levins 1970, Taylor 1990, Hanski and Gilpin 1991) all predict that isolated populations are more susceptible to extinction than connected populations. Establishing connections among natural lands has therefore long been recognized as important for sustaining natural ecological processes and biological diversity (Noss 1987, Harris and Gallagher 1989, Noss 1991, Beier and Loe 1992, Noss 1992, Beier 1993, Forman 1995, Beier and Noss 1998, Hunter 1999, Crooks and Soulé 1999, Soulé and Terborgh 1999, Penrod et al. 2001, Crooks et al. 2001, Tewksbury et al. 2002, Forman et al. 2003).

Patterns of Habitat Conversion

As a consequence of rapid habitat conversion to urban and agricultural uses, the South Coast Ecoregion of California (Figure 1) has become a hotspot for species at risk of extinction. California has the greatest number of threatened and endangered species in the continental U.S., representing nearly every taxonomic group, from plants and invertebrates to birds, mammals, fish, amphibians, and reptiles (Wilcove et al. 1998). In an analysis that identified "irreplaceable" places for preventing species extinctions (Stein et al. 2000), the South Coast Ecoregion stood out as one of the six most important areas in the United States (along with Hawaii, the San Francisco Bay Area, Southern Appalachians, Death Valley, and the Florida Panhandle). The ecoregion is part of the California Floristic Province, one of 25 global hotspots of biodiversity, and the only one in North America (Mittermeier et al. 1998, Mittermeier et al. 1999).

A major reason for regional declines in native species is the pattern of habitat loss. Species that once moved freely through a mosaic of natural vegetation types are now confronted with a man-made labyrinth of barriers, such as roads, homes, businesses, and agricultural fields that fragment formerly expansive natural landscapes. Movement patterns crucial to species survival are being permanently altered at unprecedented rates. Countering this threat requires a systematic approach for identifying, protecting, and restoring functional connections across the landscape to allow essential ecological processes to continue operating as they have for millennia.

A Statewide Vision

In November 2000, a coalition of conservation and research organizations (California State Parks, California Wilderness Coalition, The Nature Conservancy, Zoological Society of San Diego's Center for Reproduction of Endangered Species, and U.S. Geological Survey) launched a statewide interagency workshop at the San Diego Zoo entitled "Missing Linkages: Restoring Connectivity to the California Landscape". The workshop brought together over 200 land managers and conservation ecologists representing federal, state, and local agencies, academic institutions, and non-governmental organizations to delineate habitat linkages critical for preserving the State's biodiversity. Of the 232 linkages identified at the workshop, 69 are associated with the South Coast Ecoregion (Penrod et al. 2001).

Figure 1. South Coast Ecoregion encompasses roughly 8% of California and extends 300 km (190 mi) into Baja California.

South Coast Missing Linkages: A Vision for the Ecoregion

Following the statewide Missing Linkages conference, South Coast Wildlands, a non-profit organization established to pursue habitat connectivity planning in the South Coast Ecoregion, brought together regional ecologists to conduct a formal evaluation of these 69 linkages. The evaluation was designed to assess the biological irreplaceability and vulnerability of each linkage (*sensu* Noss et al. 2002). Irreplaceability assessed the relative biological value of each linkage, including both terrestrial and aquatic criteria: 1) size of habitat blocks served by the linkage; 2) quality of existing habitat in the smaller habitat block; 3) quality and amount of existing habitat in the proposed linkage; 4) linkage to other ecoregions or key to movement through the ecoregion; 5) facilitation of seasonal movement and responses to climatic change; and 6) addition of value for aquatic ecosystems. Vulnerability was evaluated using recent high-resolution aerial

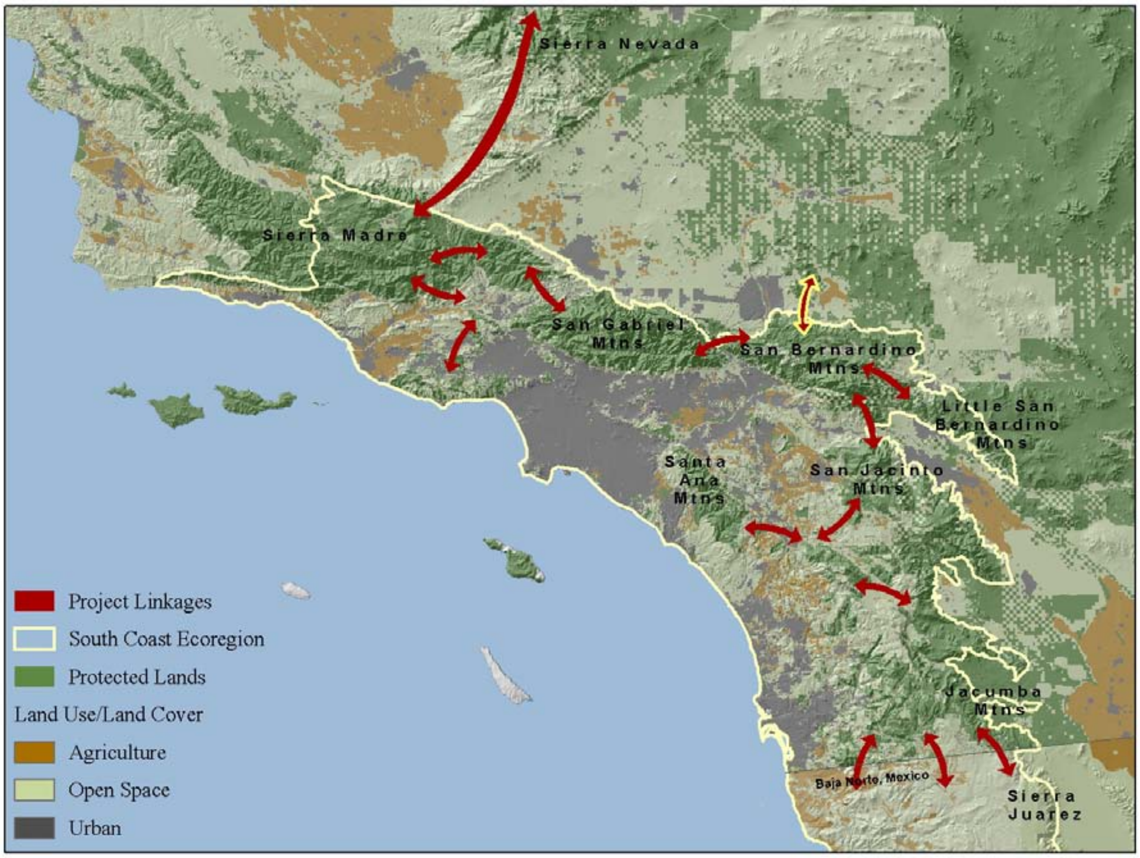

Figure 2. The South Coast Missing Linkages Project addresses habitat fragmentation at a landscape scale, and the needs of a variety of species. The San Bernardino-Granite Mountains Connection is one of 15 landscape linkages identified as irreplaceable and imminently threatened.

photographs, local planning documents, and other data concerning threats of habitat loss or fragmentation in the linkage area. This process identified 15 linkages of crucial biological value that are likely to be irretrievably compromised by development projects over the next decade unless immediate conservation action occurs (Figure 2). The biological integrity of several thousand square miles of the very best southern California wildlands would be irreversibly jeopardized if these linkages were lost.

Identification of these 15 priority linkages launched the South Coast Missing Linkages Project. This project is a highly collaborative effort among federal and state agencies and non-governmental organizations to identify and conserve landscape-level habitat linkages to protect essential biological and ecological processes in the South Coast Ecoregion. Partners include but are not limited to: South Coast Wildlands, The Wildlands Conservancy, The Resources Agency California Legacy Project, California State Parks, California State Parks Foundation, United States Forest Service, National Park Service, Santa Monica Mountains Conservancy, Rivers and Mountains Conservancy, Conservation Biology Institute, San Diego State University Field Stations Program, The Nature Conservancy, Southern California Wetlands Recovery Project, Environment Now, Mountain Lion Foundation, and the Zoological Society of San Diego's

Center for Reproduction of Endangered Species (now called Conservation and Research for Endangered Species). Cross-border alliances have also been formed with Pronatura, Universidad Autonoma de Baja California, and Conabio to further the South Coast Missing Linkages initiative in northern Baja. It is our hope that the South Coast Missing Linkages Project will serve as a catalyst for directing funds and attention toward the protection of ecological connectivity for the South Coast Ecoregion and beyond.

The 15 Priority Linkages

Santa Monica Mountains-Santa Susana Mountains
Santa Susana Mountains-Sierra Madre Mountains
Sierra Madre Mountains-Castaic Ranges
Sierra Madre Mountains-Sierra Nevada Mountains
San Gabriel Mountains-Castaic Ranges
San Bernardino Mountains-San Gabriel Mountains
San Bernardino Mountains-San Jacinto Mountains
San Bernardino Mountains-Little San Bernardino Mountains
San Bernardino Mountains-Granite Mountains
Santa Ana Mountains-Palomar Ranges
Palomar Ranges-San Jacinto/Santa Rosa Mountains
Peninsular Ranges-Anza Borrego
Laguna Mountains-Otay Mountain-Northern Baja
Campo Valley-Laguna Mountains
Jacumba Mountains-Sierra Juarez Mountains

To this end, South Coast Wildlands is coordinating and hosting regional workshops, providing resources to partnering organizations, conducting systematic GIS analyses for all 15 linkages, and helping to raise public awareness regarding habitat connectivity needs in the ecoregion. South Coast Wildlands has taken the lead in researching and planning for 8 of the 15 linkages; San Diego State University Field Station Programs, National Park Service, California State Parks, U. S. Forest Service, Santa Monica Mountains Conservancy, Conservation Biology Institute, and The Nature Conservancy have taken the lead on the other 7 linkages. The San Bernardino-Granite Mountains Connection is one of these 15 linkages, whose protection is crucial to maintaining ecological and evolutionary processes among large blocks of protected habitat within the South Coast Ecoregion.

Ecological Significance of the San Bernardino-Granite Mountains Connection

The San Bernardino-Granite Mountains Connection occurs in a transition zone between the South Coast and the Mojave Desert ecoregions, linking the San Bernardino Mountains to the inland desert ranges of the Granite, Ord and Rodman mountains. As such, the planning area encompasses both coastal and desert habitat types (Figure 3). The northern flank of the San Bernardino Mountains are steep, with forested habitats at higher elevations, juniper woodlands on the slopes, giving way to creosote bush scrub with scattered Joshua trees and a diversity of cactus at lower elevations. A rich riparian community occurs in Grapevine Canyon in the San Bernardino Mountains that shifts into desert wash habitat as it flows through Fifteenmile Valley towards Rabbit Lake at the base of the Granite Mountains. An extremely rare alkali seep plant community occurs at Rabbit Springs that supports two imperiled plant species, salt spring checkerbloom (*Sidalcea neomexicana*) and Parish's alkali grass (*Puccinellia parishii*) (BLM 2003, 2005, CDFG 2005). Creosote bush scrub, sagebrush and saltbush scrub communities dominate the jagged hills and sloping bajadas of the desert ranges.

This variety of coastal and desert habitats support a diversity of organisms, including many species listed as endangered, threatened, or sensitive by government agencies (USFWS 1994, Stephenson and Calcarone 1999, BLM 2005, CDFG 2005). A number of

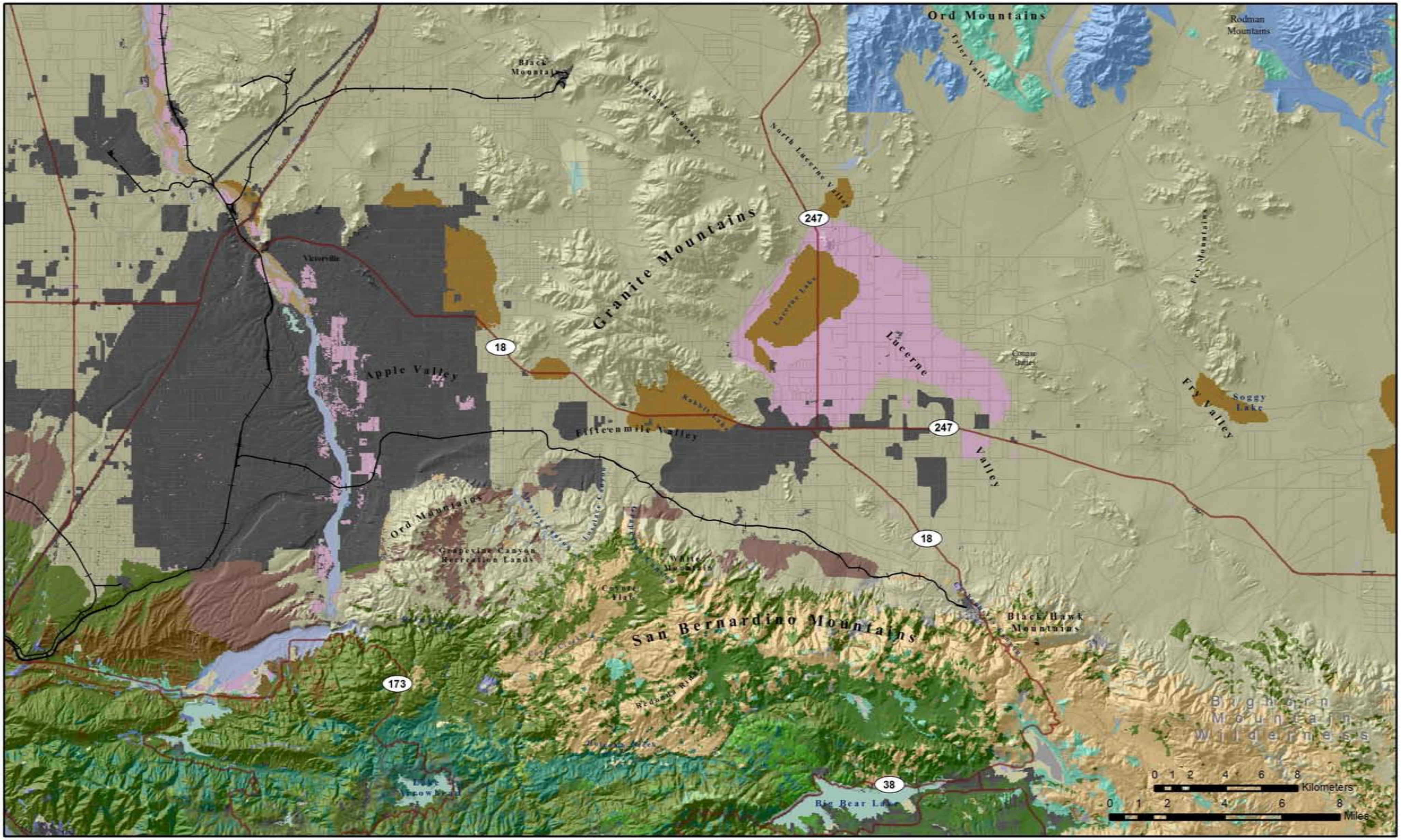

**Figure 3.
Vegetation Types
in the
Linkage Planning Area**

Agriculture
Alkali Desert Scrub
Alpine-Dwarf Shrub
Annual Grassland
Barren
Chamise-Redshank Chaparral
Closed-Cone Pine-Cypress
Coastal Oak Woodland
Coastal Scrub
Desert Riparian
Desert Scrub
Desert Succulent Shrub
Desert Wash
Eastside Pine
Eucalyptus
Freshwater Emergent Wetland
Jeffrey Pine
Joshua Tree
Juniper
Lacustrine
Lodgepole Pine
Mixed Chaparral
Montane Chaparral
Montane Hardwood
Montane Hardwood-Conifer
Montane Riparian
Palm Oasis
Perennial Grassland
Pinyon-Juniper
Ponderosa Pine
Riverine
Sagebrush
Saline Emergent Wetland
Sierran Mixed Conifer
Subalpine Conifer
Urban
Valley Foothill Riparian
Water
Wet Meadow
White Fir

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rare species depend on the area's riparian habitats, which provide breeding locations for many riparian birds and critical watering areas for Nelson's bighorn sheep (*Ovis canadensis nelsoni*). The Environmental Impact Report and Statement for the West Mojave Plan reinforced the importance of this connection to enhance dispersal opportunities for bighorn sheep (BLM 2003, 2005). Several riparian songbirds, such as summer tanager (*Piranga rubra*), gray vireo (*Vireo vicinior*) and yellow-breasted chat (*Icteria virens*) have the potential to occur, as do a number of sensitive upland bird species such as the LeConte's thrasher (*Toxostoma lecontei*) and Bendire's thrasher (*T. bendirei*) (CDFG 2005, BLM 2005). Sensitive reptiles that prefer drier habitats and sparser vegetative cover, such as the threatened desert tortoise (*Gopherus agassizii*), rosy boa (*Lichanura trivirgata*), and coast horned lizard (*Phrynosoma coronatum blainvillei*), also have the potential to occur. Desert tortoises have been documented in the linkage (CDFG 2005), and they occur along the northern base of the San Bernardino Mountains (Stephenson and Calcarone 1999), and in the Desert Tortoise Wildlife Management Area (BLM 2005). Historical records for the Mojave ground squirrel (*Spermophilus mohavensis*) also occur in both Apple Valley and Lucerne Valley (BLM 2005). The planning area also provides habitat for a number of sensitive bat species, such as the pale big-eared bat (*Corynorhinus townsendii pallescens*) and long-eared myotis (Myotis evotis).

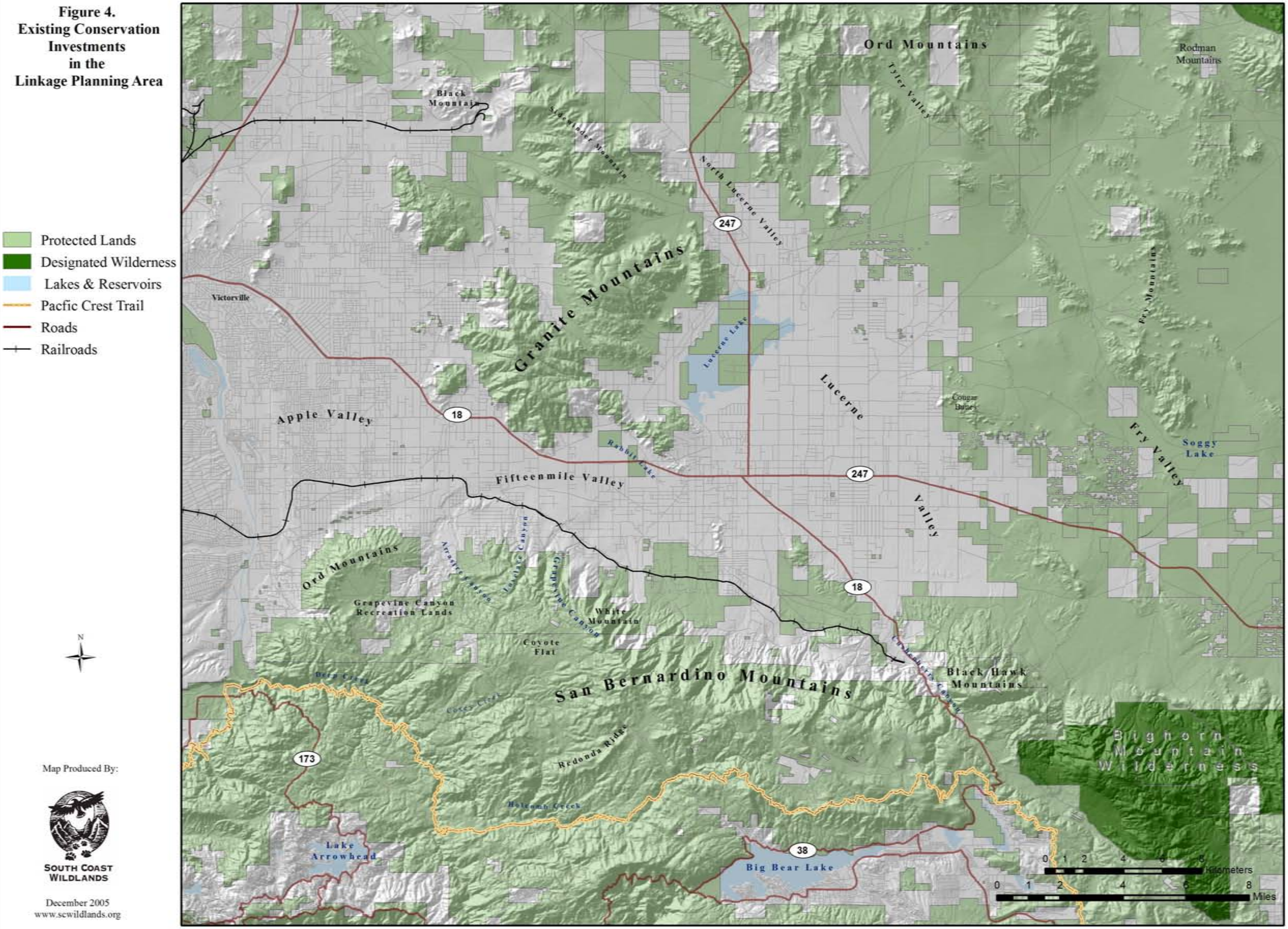
In addition to providing habitat for rare and endangered species, the linkage provides live-in and move-through habitat for numerous native species such as Nelson's bighorn sheep and American badger, that may be less extinction prone but that nevertheless require extensive wildlands to thrive.

Existing Conservation Investments

Significant conservation investments already exist in the region (Figure 4), but the resource values they support could be irreparably harmed by loss of connections between them. The USFS administers the majority of land in the San Bernardino Mountains, while BLM manages Grapevine Canyon National Recreation Lands and the Bighorn Mountain and Whitewater River National Recreation Lands in the San Bernardino Mountains and most of the targeted ranges in the desert. Some of the land in the eastern portion of the linkage has already been protected though successful conservation planning efforts undertaken by USFS, BLM, State Lands Commission, and California Department of Fish and Game, although gaps in protection remain.

Several specially designated conservation areas have been established in the planning area to protect threatened, endangered and sensitive species and natural communities. To protect ancient plant species, Soggy Dry Lake Creosote Rings and the Upper Johnson Valley Yucca Rings have been designated as Areas of Critical Environmental Concern and the King Clone Ecological Reserve has been created (BLM 2005). The Desert Tortoise Conservation Area encompasses most of the core areas targeted in the desert. Another conservation area has been established just north of Lucerne Valley in the Brisbane Valley to protect the Mojave monkeyflower (*Mimulus mohavensis*). And a conservation area for carbonate endemic plants has been designated in the foothills of the San Bernardino Mountains to protect this rare and endangered plant community, as well as habitat for gray vireo and bighorn sheep (BLM 2005). The value of already protected land in the region for biodiversity conservation, environmental education, outdoor recreation, and scenic beauty is immense.

**Figure 4.
Existing Conservation
Investments
in the
Linkage Planning Area**



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Southern California's remaining wildlands form an archipelago of natural open space thrust into one of the world's largest metropolitan areas within a global hotspot of biological diversity. These wild areas are naturally interconnected; indeed, they historically functioned as one ecological system. However, recent intensive and unsustainable activities threaten to sever natural connections, forever altering the functional integrity of this remarkable natural system. The ecological, educational, recreational, and spiritual impacts of such a severance would be substantial. Certainly, maintaining and restoring functional habitat connectivity to this regionally important landscape linkage is a wise investment.

Conservation Planning Approach

The goal of linkage conservation planning is to identify specific lands that must be conserved to maintain or restore functional connections for all species or ecological processes of interest, generally between two or more protected core habitat areas. We adopted a spatially hierarchical approach, gradually working from landscape-level processes down to the needs of individual species on the ground. The planning area encompasses habitats between protected areas in the San Bernardino Mountains and the Granite, Ord, and Rodman Mountains. We conducted various landscape analyses to identify those areas necessary to accommodate continued movement of selected focal species through this landscape. Our approach can be summarized as follows:

1) *Focal Species Selection:* Select focal species from diverse taxonomic groups to represent a diversity of habitat requirements and movement needs.

2) *Landscape Permeability Analysis:* Conduct landscape permeability analyses to identify a zone of habitat that addresses the needs of multiple species potentially traveling through or residing in the linkage.

3) *Patch Size & Configuration Analysis:* Use patch size and configuration analyses to identify the priority areas needed to maintain linkage function.

4) *Field Investigations:* Conduct fieldwork to ground-truth results of prioritization analyses, identify barriers, and document conservation management needs.

5) *Linkage Design:* Compile results of analyses and fieldwork into a comprehensive report detailing what is required to conserve and improve linkage function.

Our approach has been highly collaborative and interdisciplinary (Beier et al. 2005). We followed Baxter (2001) in recognizing that successful conservation planning is based on the participation of experts in biology, conservation design, and implementation in a reiterative process (Figure 5). To engage regional biologists and planners early in the process, we held a habitat connectivity workshop on August 7, 2002. The workshop gathered indispensable information on conservation needs and opportunities in the linkage. The workshop engaged 86 participants representing over 44 different agencies, academic institutions, conservation organizations, and community groups (Appendix A).

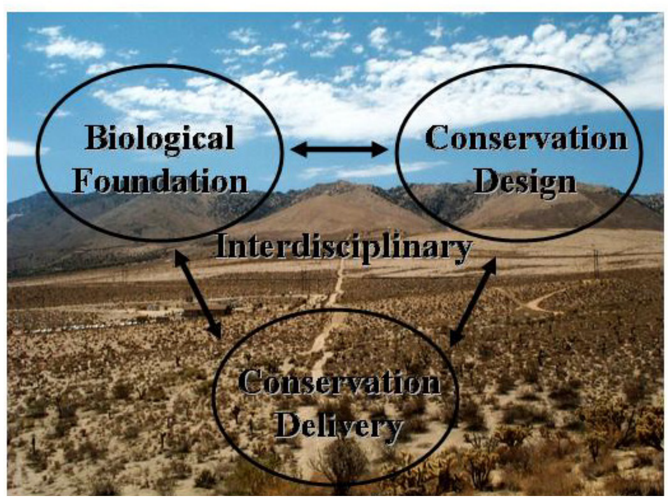


Figure 5. Successful conservation planning requires an interdisciplinary and reiterative approach among biologists, planners and activists (Baxter 2001).

Focal Species Selection

Table 1. Regional ecologists selected 14 focal species for the San Bernardino-Granite Connection
PLANTS
Yucca brevifolia (Joshua tree)
INVERTEBRATES
Eleodes armata (Desert skunk beetle)*
Apodemia mormo (Metalmark butterfly)
Callophrys perplexa (Green hairstreak butterfly)
Pepsis spp. (Tarantula hawks)
REPTILES
Crotalus mitchellii (Speckled rattlesnake)
BIRDS
Campylorhynchus brunneicapillus (Cactus wren)
Salpinctes obsoletus (Rock wren)
MAMMALS
Dipodomys agilis (Pacific kangaroo rat)
Dipodomys merriami (Merriam's kangaroo rat)
Neotoma lepida (Desert woodrat)
Ammospermophilus leucurus (Antelope ground squirrel)
Ovis canadensis nelsoni (Nelson's bighorn sheep)
Taxidea taxus (American badger)
** indicates species not modeled due to insufficient data.*

Workshop participants identified a taxonomically diverse group of focal species (Table 1) that are sensitive to habitat loss and fragmentation and that represent the diversity of ecological interactions that can be sustained by successful linkage design. The focal species approach (Beier and Loe 1992) recognizes that species move through and utilize habitat in a wide variety of ways. Workshop participants divided into taxonomic working groups; each group identified life history characteristics of species that were either particularly sensitive to habitat fragmentation or otherwise meaningful to linkage design. Participants then summarized the relevant information on species occurrences, movement characteristics, and habitat preferences and delineated suitable habitat and potential movement routes through the linkage (For more on the workshop see Appendix B).

The 14 focal species identified at the workshop capture a diversity of movement needs and ecological requirements, from species that require large tracts of land (e.g., badger, bighorn sheep) to those with limited spatial requirements (e.g., desert woodrat). They include habitat specialists (e.g., cactus wren) and those requiring a specific configuration of habitat types and elements (e.g., tarantula hawks that require hilltopping habitat). Dispersal distance capability of focal species ranges from 80 m to 110 km; modes of dispersal include flying, slithering, climbing, and walking.

Landscape Permeability Analysis

Landscape permeability analysis is a GIS technique that models the relative cost for a species to move between core areas based on how each species is affected by habitat characteristics, such as slope, elevation, vegetation composition, and road density. This analysis identifies a least-cost corridor, or the best potential route for each species between protected core areas (Walker and Craighead 1997, Craighead et al. 2001, Singleton et al. 2002). The purpose of the analysis was to identify land areas that would best accommodate all focal species living in or moving through the linkage.

Species used in landscape permeability analysis must be carefully chosen, and were included in this analysis only if:

- We know enough about the movement of the species to reasonably estimate the cost-weighted distance using the data layers available to our analysis.

- The data layers in the analysis reflect the species' ability to move.
- The species occurs in both cores (or historically did so and could be restored) and can potentially move between cores, at least over multiple generations.
- The time scale of gene flow between core areas is shorter than, or not much longer than, the time scale at which currently mapped vegetation is likely to change due to disturbance events and environmental variation (e.g. climatic changes).

Three species were found to meet these criteria and were used in permeability analyses to identify the least-cost corridor between protected core areas: American badger, Nelson's bighorn sheep, and Pacific kangaroo rat. Ranks and weightings adopted for each species are shown in Table 2.

The relative cost of travel was assigned for each of these 3 focal species based upon its ease of movement through a suite of landscape characteristics (vegetation type, road density, and topographic features). The following spatial data layers were assembled at 30-m resolution: vegetation, roads, elevation, and topographic features (Figure 6). We derived 4 topographic classes from elevation and slope models: canyon bottoms, ridgelines, flats, or slopes. Road density was measured as kilometers of paved road per square kilometer. Within each data layer, we ranked all categories between 1 (preferred) and 10 (avoided) based on focal species preferences as determined from available literature and expert opinion regarding how movement is facilitated or hindered by natural and urban landscape characteristics. Each input category was ranked and weighted, such that:

(Land Cover * w%) + (Road Density * x%) + (Topography * y%) + (Elevation * z%) = Cost to Movement, where w + x + y + z = 100%.

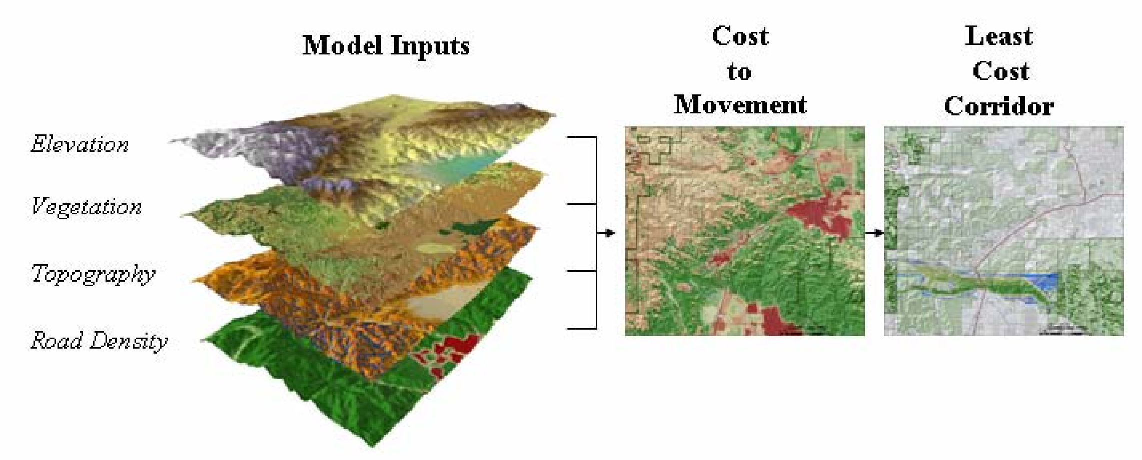


Figure 6. Permeability Model Inputs: elevation, vegetation, topography, and road density. Landscape permeability analysis models the relative cost for a species to move between core areas based on how each species is affected by various landscape characteristics.

Table 2. Model Parameters for Landscape Permeability Analyses

	Dipodomys agilis (Pacific kangaroo rat)	*Ovis canadensis* (Nelson's bighorn sheep)	*Taxidea taxus* (American Badger)
MODEL VARIABLES			
VEGETATION			
Alpine-Dwarf Shrub	10	2	4
Agriculture	10	9	7
Annual Grassland	4	5	1
Alkali Desert Scrub	9	1	2
Barren	7	2	9
Bitterbrush	10	3	3
Blue Oak-Foothill Pine	7	9	5
Blue Oak Woodland	7	9	5
Coastal Oak Woodland	7	9	5
Closed-Cone Pine-Cypress	10	9	6
Chamise-Redshank Chaparral	5	9	4
Coastal Scrub	2	9	4
Desert Riparian	7	1	3
Desert Scrub	6	1	2
Desert Succulent Shrub	6	1	2
Desert Wash	9	1	3
Eastside Pine	10	9	5
Estuarine	10	10	10
Freshwater Emergent Wetland	10	8	9
Jeffrey Pine	9	9	5
Joshua Tree	3	3	2
Juniper	7	3	3
Lacustrine	10	10	9
Lodgepole Pine	10	9	6
Mixed Chaparral	5	9	4
Montane Chaparral	5	1	4
Montane Hardwood-Conifer	9	2	6
Montane Hardwood	9	2	6
Montane Riparian	10	2	6
Perennial Grassland	4	5	1
Pinyon-Juniper	7	8	3
Palm Oasis	10	1	6
Ponderosa Pine	9	9	5
Riverine	10	10	9
Red Fir	10	9	6
Subalpine Conifer	10	2	6
Saline Emergent Wetland	10	10	10
Sagebrush	10	3	3
Sierran Mixed Conifer	10	9	6
Urban	10	8	10

Table 2. continued	*Dipodomys agilis* (Pacific kangaroo rat)	*Ovis candadensis* (Nelson's bighorn sheep)	*Taxidea taxus* (American Badger)
MODEL VARIABLES			
Valley Oak Woodland	7	9	4
Valley Foothill Riparian	7	9	4
Water	10	10	10
White Fir	10	9	6
Wet Meadow	10	8	4
Unknown Shrub Type	10	9	5
Unknown Conifer Type	10	9	5
Eucalyptus	8	9	6
ROAD DENSITY			
0-0.5 km/sq. km	1	1	1
0.5-1 km/sq. km	1	2	1
1-2 km/sq. km	2	4	2
2-4 km/sq. km	3	8	2
4-6 km/sq.km	3	10	4
6-8 km/sq. km	9	10	7
8-10 km/sq.km	10	10	10
10 or more km/sq. km	10	10	10
TOPOGRAPHY			
Canyon bottoms	3	1	2
Ridgetops	3	1	7
Flats	1	5	1
Slopes	7	1	9
ELEVATION (feet)			
-260-0	4	N/A	1
0-500	1		1
500-750	1		1
750-1000	1		1
1000-3000	1		2
3000-5000	1		3
5000-7000	3		3
7000-8000	6		5
8000-9000	9		5
9000-11500	9		5
>11500	10		8
WEIGHTS			
Land Cover	0.70	0.40	0.55
Road Density	0.10	0.20	0.15
Topography	0.10	0.40	0.20
Elevation	0.10	0.00	0.10

Weighting allowed the model to capture variation in the influence of each input (vegetation, road density, topography, elevation) on focal species movements. A unique cost surface was thus developed for each species. A corridor function was then performed in GIS to generate a data layer showing the relative degree of permeability between core areas.

Running the permeability analysis required identifying the endpoints to be connected. Usually, these targeted endpoints are selected as medium to highly suitable habitat within protected core habitat areas (e.g., National Forests, BLM lands) that needed to be connected through currently unprotected lands. However, since much of the land in the eastern portion of the linkage was already protected (i.e., Bureau of Land Management and Department of Fish and Game), we selected endpoints for this analysis as protected areas supporting medium to highly suitable habitat for each species in the San Bernardino National Forest and BLM lands in the Granite, Ord, and Rodman Mountains. This gave the model broad latitude in interpreting functional corridors across the entire study area. For each focal species, the most permeable area of the study window was designated as the least-cost corridor.

The least cost corridor output for all three species was then combined to generate a Least Cost Union. The biological significance of this Union can best be described as the zone within which all three modeled species would encounter the least energy expenditure (i.e., preferred travel route) and the most favorable habitat as they move between targeted protected areas. The output does not identify barriers (which were later identified through fieldwork), mortality risks, dispersal limitations or other biologically significant processes that could prevent a species from successfully reaching a core area. Rather, it identifies the best zone available for focal species movement based on the data layers used in the analyses.

Patch Size & Configuration Analysis

Although the Least Cost Union identifies the best zone available for movement based on the data layers used in the analyses, it does not address whether suitable habitat in the Union occurs in large enough patches to support viable populations and whether these patches are close enough together to allow for inter-patch dispersal. We therefore conducted patch size and configuration analyses for all focal species (Table 1) and adjusted the boundaries of the Least Cost Union where necessary to enhance the likelihood of movement. Patch size and configuration analyses are particularly important for species that require multiple generations to traverse the linkage. Many species exhibit metapopulation dynamics, whereby the long-term persistence of a local population requires connections to other populations (Hanski and Gilpin 1991). For relatively sedentary species like Pacific kangaroo rat and terrestrial insects, gene flow through the linkage will occur over decades through a metapopulation. Thus, the linkage must be able to accommodate metapopulation dynamics to support ecological and evolutionary processes in the long term.

A habitat suitability model formed the basis of the patch size and configuration analyses. Habitat suitability models were developed for each focal species using the literature and expert opinion. Spatial data layers used in the analysis varied by species and included: vegetation, elevation, topographic features, slope, aspect, hydrography, and soils. Using scoring and weighting schemes similar to those described in the previous section, we generated a spectrum of suitability scores that were divided into 5 classes using natural breaks: low, low to medium, medium, medium to high, or high. Suitable habitat was identified as all land that scored medium, medium to high, or high.

To identify areas of suitable habitat that were large enough to provide a significant resource for individuals in the linkage, we conducted a patch size analysis. The size of all suitable habitat patches in the planning area were identified and marked as potential cores, patches, or less than a patch. *Potential core areas* were defined as the amount of contiguous suitable habitat necessary to sustain at least 50 individuals. A *patch* was defined as the area of contiguous suitable habitat needed to support at least one male and one female, but less than the potential core area. Potential cores are probably capable of supporting the species for several generations (although with erosion of genetic material if isolated). Patches can support at least one breeding pair of animals (perhaps more if home ranges overlap greatly) and are probably useful to the species if the patch can be linked via dispersal to other patches and core areas (Figure 7).

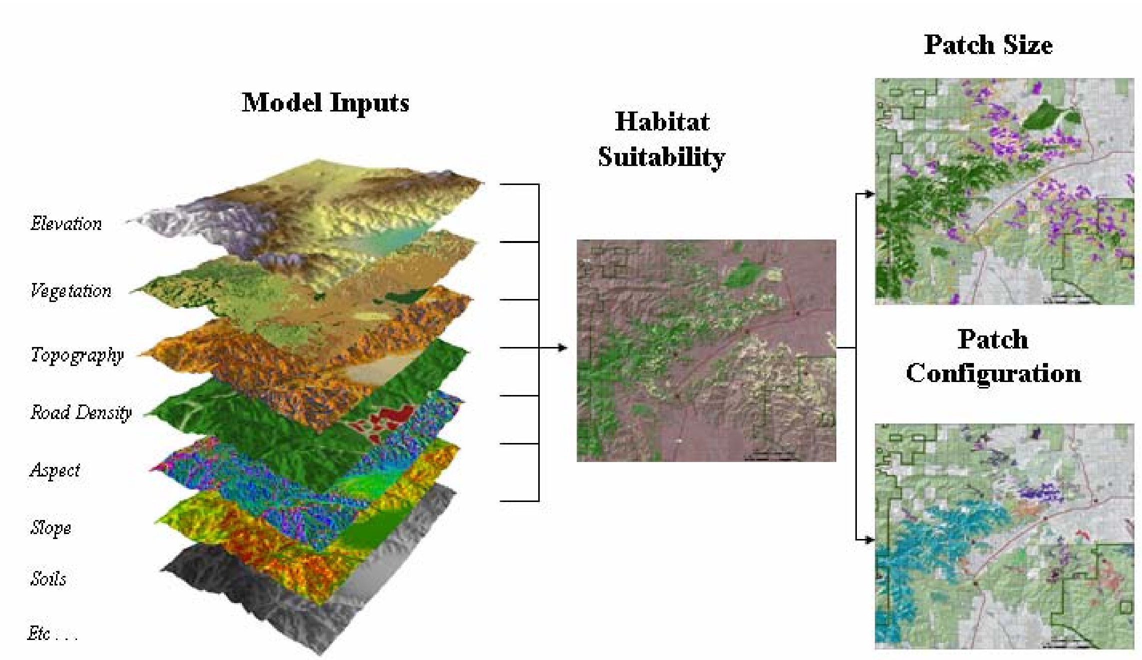


Figure 7. Model Inputs to Patch Size and Configuration Analyses vary by species. Patch size delineates cores, patches, and stepping-stones of potential habitat. Patch configuration evaluates whether suitable habitat patches and cores are within each species dispersal distance.

To determine whether the distribution of suitable habitat in the linkage supports meta-population processes and allows species to disperse among patches and core areas, we conducted a configuration analysis to identify which patches and core areas were functionally isolated by distances too great for the focal species to traverse. Because the majority of methods used to document dispersal distance underestimate the true value (LaHaye et al. 2001), we assumed each species could disperse twice as far as the longest documented dispersal distance. This assumption is conservative in the sense that it retains habitat patches as potentially important to dispersal for a species even if it may appear to be isolated based on known dispersal distances. Groupings of core areas and patches that were greater than the adopted dispersal distance from other suitable habitat were identified using a unique color.

For each species we compared the configuration and extent of potential cores and patches, relative to the species dispersal ability, to evaluate whether the Least Cost Union was likely to serve the species. If necessary, we added additional habitat to help ensure that the linkage provides sufficient live-in or "move-through" habitat for the species' needs.

Minimum Linkage Width

While the size and distance among habitats (addressed by patch size and configuration analyses) must be adequate to support species movement, the shape of those habitats also plays a key role. In particular, constriction points—areas where habitats have been narrowed by surrounding development—can prevent organisms from moving through the Least Cost Union. To ensure that functional processes are protected, we imposed a minimum width of 2 km (1.2 mi) for all portions of the final Linkage Design. Harrison (1992) proposed a minimum corridor width for a species living in a linkage as the width of one individual's territory (assuming territory width is half its length). Thus, our minimum corridor width of 2 km should accommodate species with home ranges of up to about 8 km^2 (3 mi^2).

For a variety of species, including those we did not formally model, a wide linkage helps ensure availability of appropriate habitat, host plants (e.g., for butterflies), pollinators, and areas with low predation risk. In addition, fires and floods are part of the natural disturbance regime and a wide linkage allows for a semblance of these natural disturbances to operate with minimal constraints from adjacent urban areas. A wide linkage also enhances the ability of the biota to respond to climate change (Field et al. 1999), buffers against edge effects (Murcia 1995, Suarez et al. 1998, Hall et al. 2000, Debinski and Holt 2000, Norton 2002, Kristan et al. 2003), and reduces contaminants in streams (Naicker et al. 2001, Maret and MacCoy 2002, Scott 2002).

Field Investigations

We conducted field surveys to ground-truth existing habitat conditions, document barriers and potential passageways, and describe restoration opportunities. All location data were recorded using a mobile GIS/GPS with ESRI's ArcPad. Because paved roads often present the most formidable potential barriers, biologists drove or walked each accessible section of road and railway that transected the linkage. All types of potential crossing structures (e.g., bridge, underpass, overpass, culvert, pipe) were photo documented and measured. Data taken for each crossing included: shape; height, width, and length of the passageway; stream type, if applicable (perennial or intermittent); floor type (metal, dirt, concrete, natural); passageway construction (concrete, metal, other); visibility to other side; light level; fencing; and vegetative community within and/or adjacent to the passageway. Existing highways and crossing structures are not considered permanent landscape features. In particular, crossing structures can be added or improved during projects to widen and realign highways and interchanges. Therefore, we also identified areas where crossing structures could be improved or installed, and opportunities to restore vegetation to improve road crossings and minimize roadkills.

Identify Conservation Opportunities

The Linkage Design serves as the target area for linkage conservation opportunities. We provided biological and land use summaries, and identified implementation opportunities for agencies, organizations, and individuals interested in helping conserve the San Bernardino-Granite Mountains Connection. Biological and land use summaries include descriptions and maps of vegetation, land cover, land use, roads, road crossings, and restoration opportunities. We also identified existing planning efforts addressing the conservation and use of natural resources in the planning area. Finally, we developed a flyover animation using aerial imagery, satellite imagery, and digital elevations models, which provides a visualization of the linkage from a landscape perspective (Appendix C).

Landscape Permeability Analyses

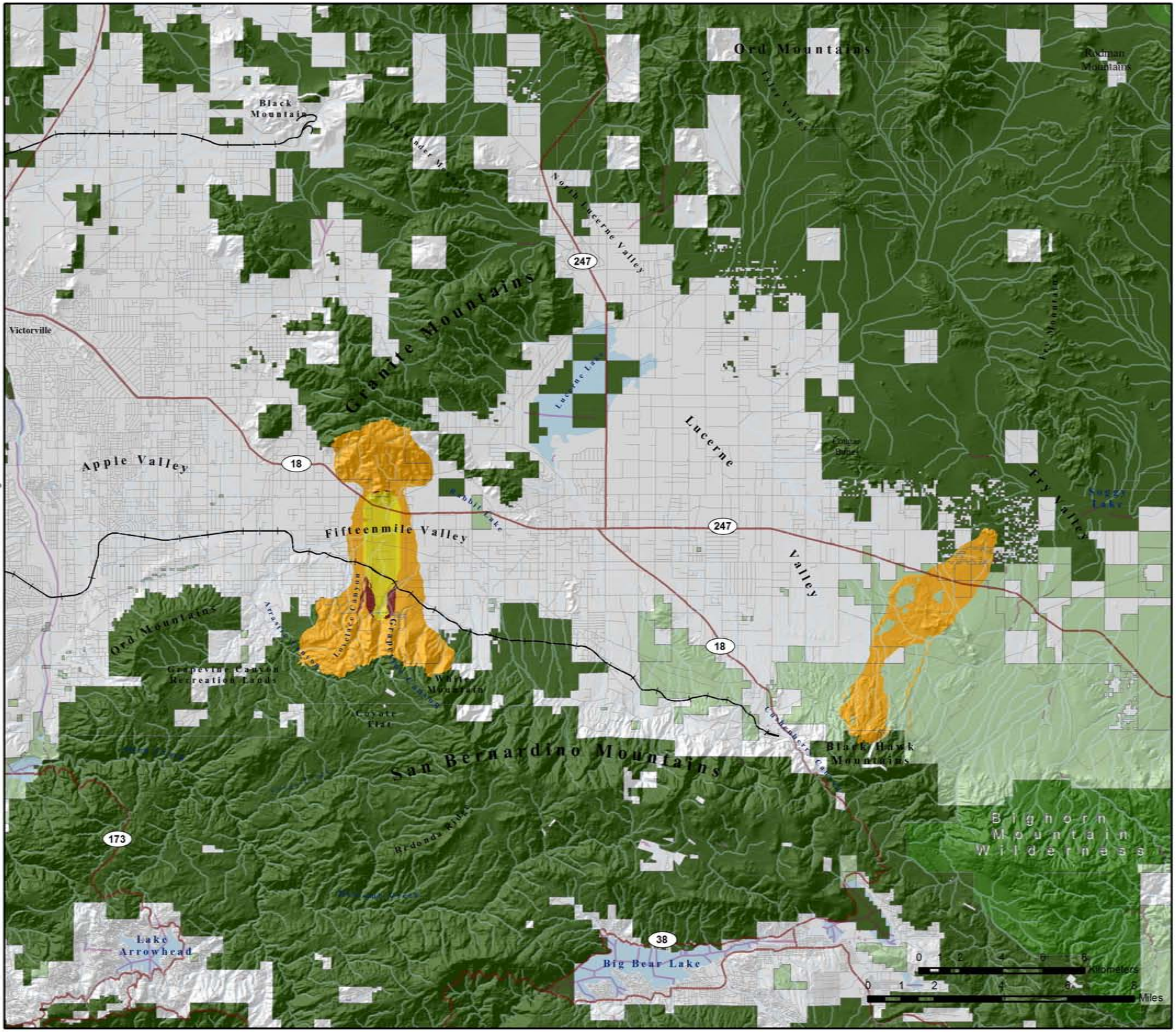
The least cost corridors for the three species we modeled (American badger, Nelson's bighorn sheep, and Pacific kangaroo rat) overlapped considerably, despite the diverse ecological and movement requirements of these species (see following species accounts and Table 2). The most permeable paths for all three species converged in the western part of the linkage, with one species, Nelson's bighorn sheep, diverging to generate an additional route (Figure 8). The similarity of the species-specific corridors is likely due to the reduction of natural habitats in the study area: remaining natural areas are limited, and for all species, cost of travel is lower through natural habitats than in areas with roads, agriculture, and urban development.

The Least Cost Union stretches about 8 km (5 mi) between protected areas in the San Bernardino Mountains and the Granite, Ord, and Rodman Mountains (Figure 9). It encompasses the transition between the South Coast and Mojave Desert ecoregions, and includes chaparral, pinyon-juniper woodland, Joshua tree woodland, desert scrub, and riparian habitats.

The Least Cost Union has two branches, roughly 24 km (15 mi) apart. The western branch is the most permeable route for all three species. It extends from Grapevine Canyon in the San Bernardino Mountains to Fifteenmile Point in the Granite Mountains, crossing State Highway 18 (or Happy Trails Highway) between the communities of Apple Valley and Lucerne Valley. Pinyon-juniper woodland, mixed chaparral, desert scrub and alkali desert scrub habitats dominate the western branch, which ranges in width from about 2 to 4 km (1.2-2.5 mi). The eastern branch extends from Black Hawk Mountain near Cushenberry Canyon in the San Bernardino Mountains, through Fry Valley to the Fry and Rodman Mountains, crossing State Highway 247 (or Old Woman Spring Road) between Lucerne and Johnson Valleys. It ranges in width from 1 to 3 km (0.6 to 1.9 mi) and encompasses Joshua tree woodland and pinyon-juniper woodland in the foothills of the San Bernardino Mountains, desert scrub through the valleys and Fry Mountains, and sagebrush habitats in the Rodman Mountains.

The next few pages summarize the permeability analyses for each of the 3-modeled species. For convenience, the narratives describe the most permeable paths from south to north; although our analyses, gave equal weight to movements in both directions. The following section (Patch Size and Configuration Analyses) describes how well the Least Cost Union would likely serve the needs of all focal species, including those for which we could not conduct permeability analysis. The latter analysis was used to confirm that the Least Cost Union provided critical live-in and/or move-through habitat for all of the selected focal species.

Figure 8. Least Cost Union with Species Overlap



- Nelson's bighorn sheep
- American badger
- Pacific kangaroo rat
- Target Areas*
- Protected Lands
- Hydrography
- Roads
- Railroads

* Analysis was run between San Bernardino National Forest boundaries and modified Bureau of Land Management boundaries.

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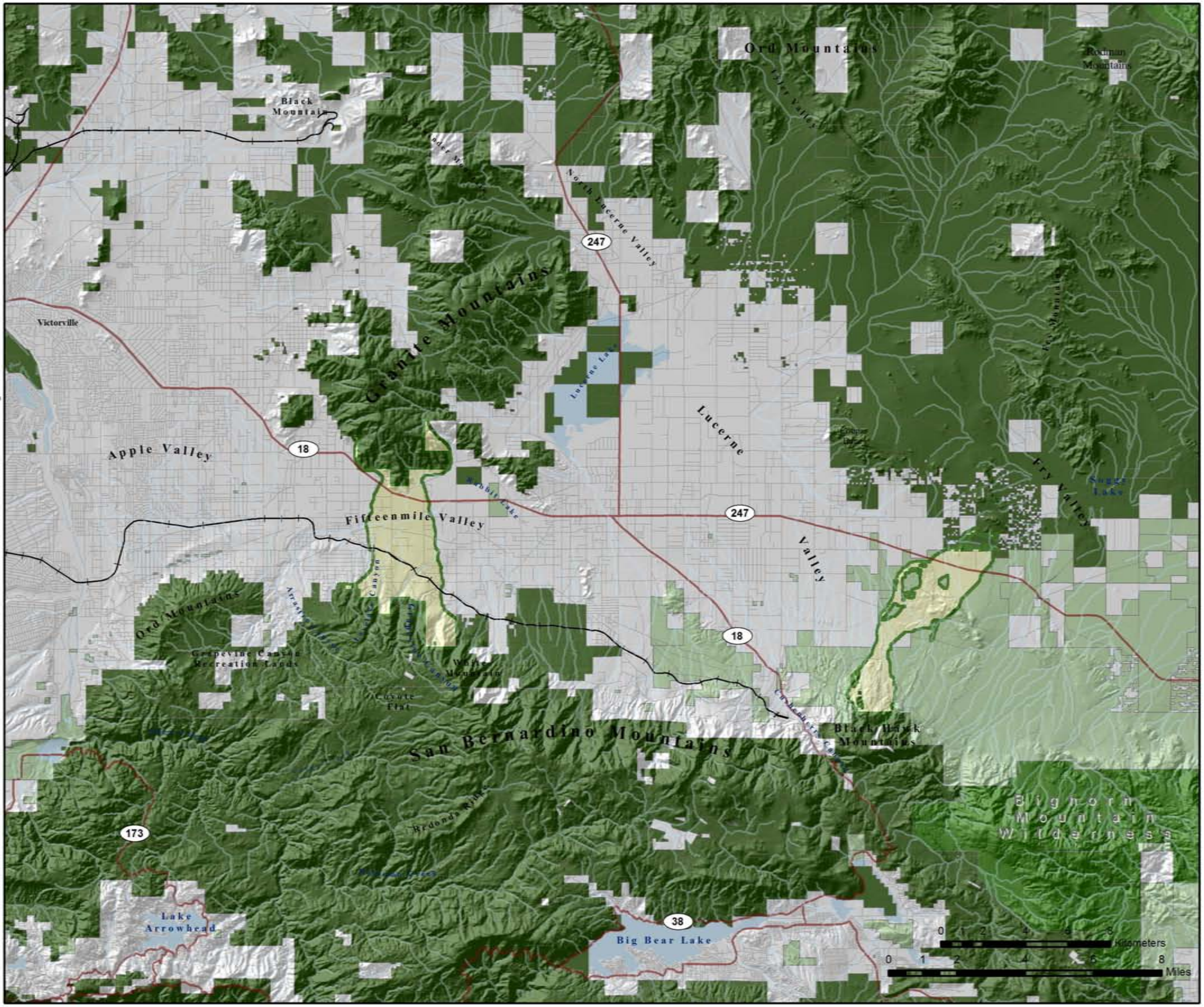
Figure 9.
Least Cost Union



- Least Cost Union
- Target Areas*
- Protected Lands
- Hydrography
- Roads
- Railroads

* Analysis was run between San Bernardino National Forest boundaries and modified Bureau of Land Management boundaries.

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American badger (*Taxidea taxus*)

Justification for Selection: The American badger is a highly specialized species that requires open habitats with suitable soils for excavating large burrows (de Vos 1969, Banfield 1974, Zeiner et al. 1990, Sullivan 1996). Badgers require expansive wildlands to survive and are highly sensitive to habitat fragmentation. In fact, roadkill is the primary cause of mortality (Long 1973, Zeiner et al. 1990, Sullivan 1996).

Conceptual Basis for Model Development: Badgers are associated with grasslands, prairies, and other open habitats that support abundant burrowing rodents (de Vos 1969, Banfield 1974, Sullivan 1996) but they may also be found in drier open stages of shrub and forest communities (Zeiner et al. 1990). They are known to inhabit forest and mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper, and sagebrush habitats (Long and Killingley 1983, Zeiner et al. 1990). The species is typically found at lower elevations (Zeiner et al. 1990) in flat, rolling or steep terrain, but it has been recorded up to 3,600 m (12,000 ft) (Minta 1993).

Badgers can disperse up to 110 km (68 mi; Lindzey 1978), and preferentially move through open scrub habitats, fields, and pastures, and open upland and riparian woodland habitats. They avoid urban and intense agricultural areas. Denser scrub and woodland habitats and orchards are less preferred. Roads are difficult to navigate safely. Table 2 presents model variable scorings for this species. Cost to movement for badger was defined by weighting these inputs as follows:

(Vegetation * 0.55) + (Elevation * 0.10) + (Topography * 0.20) + (Road Density *0.15)

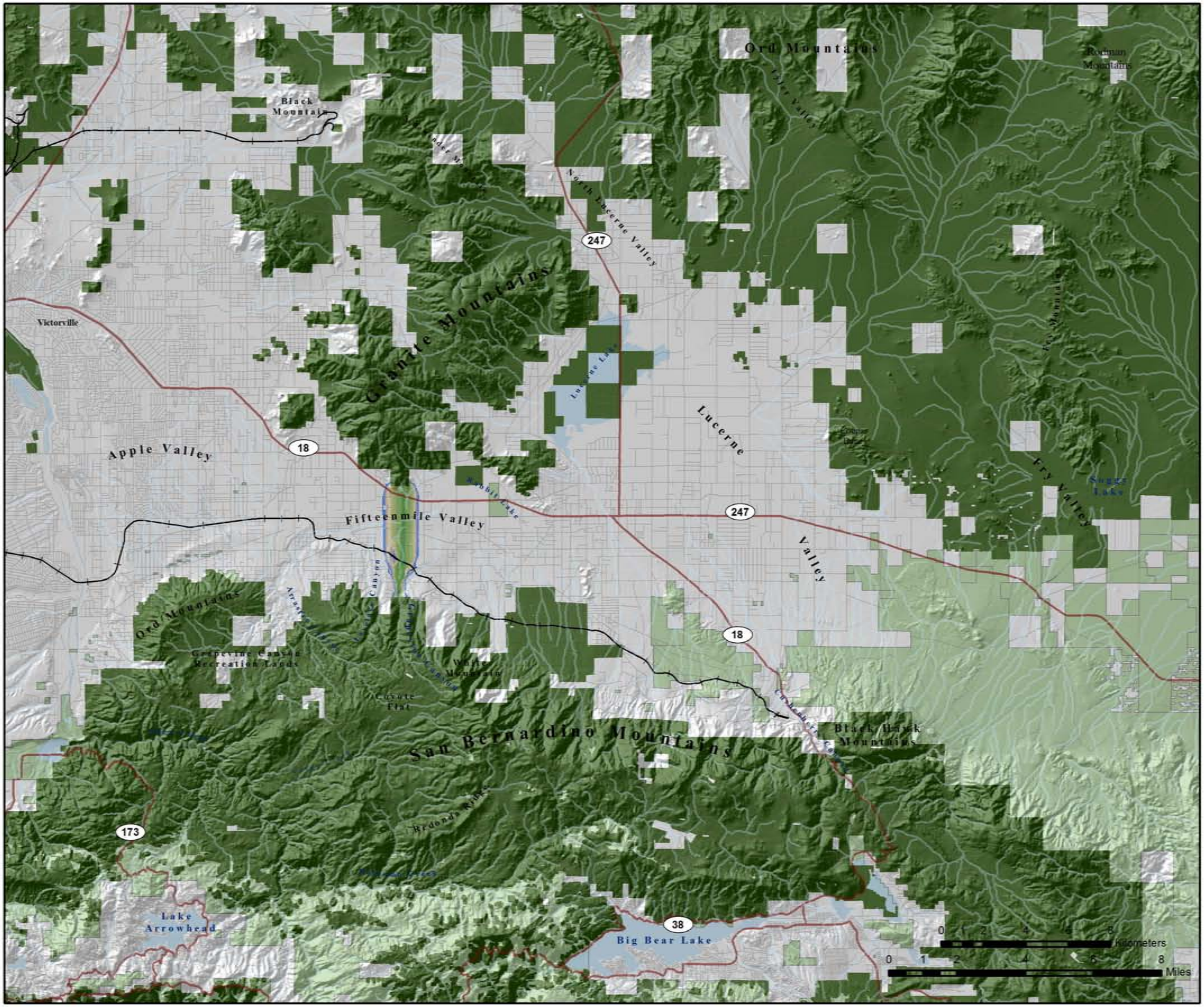
Results & Discussion: The least cost corridor for badger extends from Grapevine Canyon in the San Bernardino Mountains, through Fifteenmile Valley, to Fifteenmile Point in the Granite Mountains (Figure 10). It is roughly 5.5 km (3.4 mi) long and 0.5 to 2 km (0.3 to 1.2 mi) wide. It encompasses gently sloping topography of the low elevation foothills and relatively flat areas vegetated with juniper woodland, Joshua tree woodland, desert scrub, desert succulent scrub, and desert wash.

Figure 10.
Least Cost Corridor
for
American badger
(Taxidea taxus)

Least Cost Corridor

- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Protected Lands
- Hydrography
- Roads
- Railroads

*This analysis was run from medium to high suitable habitat within targeted protected areas.



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Nelson's bighorn sheep (*Ovis canadensis nelsoni*)

Justification for Selection: Bighorn sheep need large core wild areas for refuge and security. Their distribution is associated with mountain ranges that can be viewed as "islands" among more flat terrain, yet their persistence depends on habitat connectivity between subpopulations and populations that live in these disjunct mountains. Bighorn sheep are extremely sensitive to habitat loss and fragmentation (Bleich et al. 1996, Rubin et al. 1998, Singer et al. 2000, USFWS 2000).

Conceptual Basis for Model Development: Bighorn sheep utilize alpine dwarf shrub, low sage, sagebrush, pinyon-juniper, palm oasis, desert riparian, desert scrubs, subalpine conifer, and perennial grassland (Zeiner et al. 1990, E. Rubin, pers. com.). In the San Gabriel Mountains, they also use montane oak, conifer, and chaparral habitats (Holl and Bleich 1983). Adult rams move the most (Weaver 1972, DeForge 1980, Holl and Bleich 1983, Holl et al. 2004); with movements up to 56 km (34.8 mi) observed (Witham and Smith 1979). The longest recorded movement in the San Gabriel Mountains was about 10 km (6.2 mi) (DeForge1980), although local movement data are sparse. Bighorn sheep preferentially move through open habitats in close proximity to escape terrain, preferring ridgetops as travel routes. They avoid roads, impenetrable vegetation, urban land cover, and centers of human activity, even in suitable habitat. Please see Table 2 for model variable scorings for this species. Cost to movement for Nelson's bighorn sheep was defined by weighting these inputs as follows:

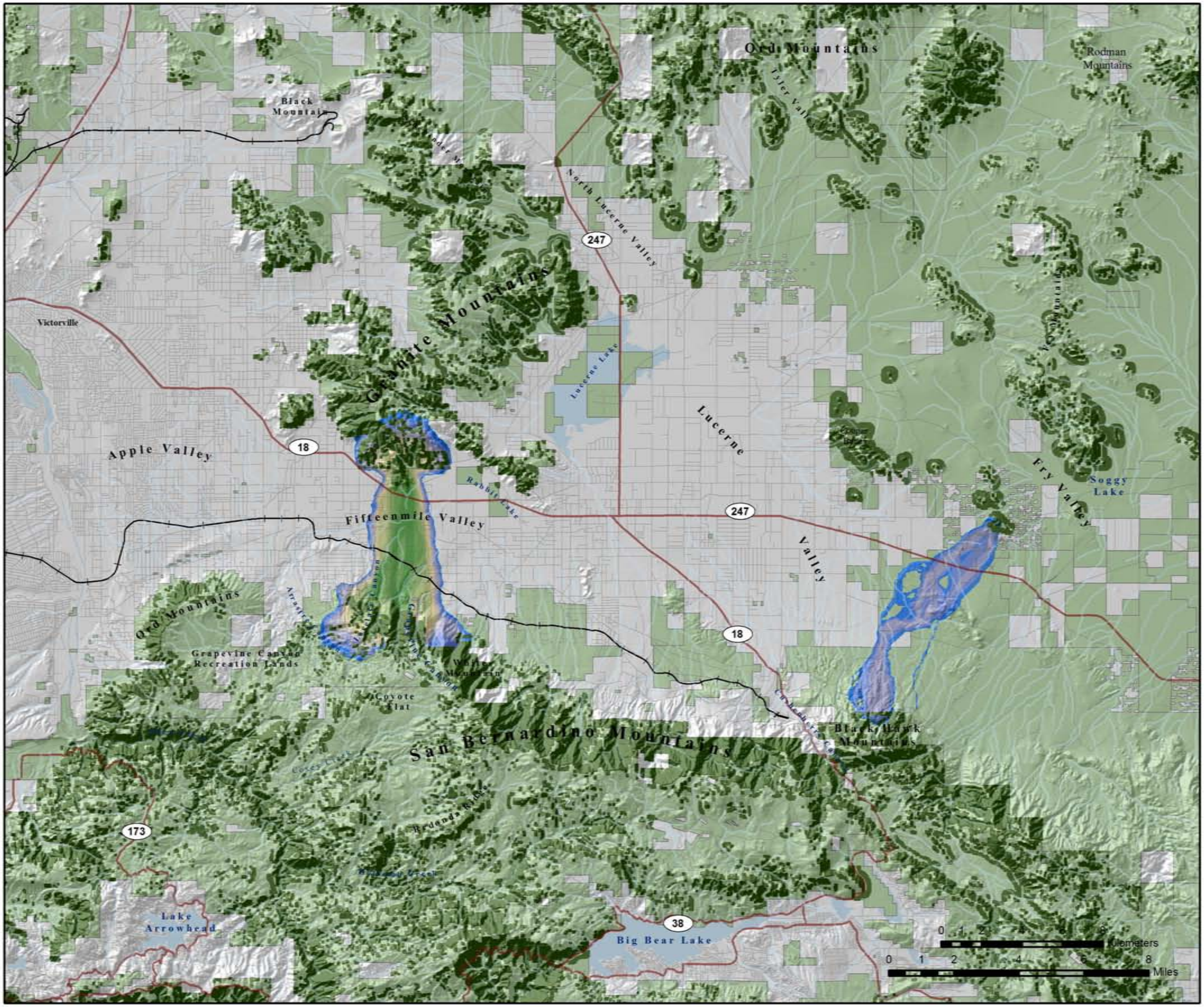
(Vegetation * 40%) + (Topography * 40%) + (Road Density * 20%)

Results & Discussion: The analysis identified 2 potential movement routes for bighorn sheep (Figure 11). The more permeable of the 2 resembles the output for badger, extending from Grapevine Canyon in the San Bernardino Mountains to Fifteenmile Point in the Granite Mountains. However, the route for bighorn sheep is much wider than that for badger, varying from 2 to 4 km (1.2 to 2.5 mi) wide. The western branch of the least cost corridor appears to be an important dispersal connection for bighorn sheep (BLM 2003, 2005). The other potential corridor is about 24 km (15 mi) to the east, just past Lucerne Valley. It ranges in width from 1 to 3 km (0.6 to 1.9 mi) and extends from Cushenberry Canyon near Black Hawk Mountain in the San Bernardino Mountains, through Fry Valley, crossing over Soggy Lake toward the Fry and Rodman Mountains. Joshua tree woodland and pinyon-juniper woodland dominate the foothills of the San Bernardino Mountains, transitioning to desert scrub through the valleys and Fry Mountains to sagebrush in the Rodman Mountains. While not identified by the model as the most permeable path, the majority of the land within this route is public land administered by the BLM.

Figure 11.
Least Cost Corridor
for
Nelson's bighorn sheep
(Ovis canadensis nelsoni)

Least Cost Corridor
- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Protected Lands
- Hydrography
- Roads
- Railroads

*This analysis was run from medium to high suitable habitat within targeted protected areas.



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Pacific kangaroo rat (*Dipodomys agilis*)

Justification for Selection: Pacific kangaroo rats are sensitive to habitat loss and fragmentation. They may cross some roads but have difficulty navigating wide or paved roads, and if they cross they are susceptible to road kill. Barriers to kangaroo rat movements may include roads, canals, and dense vegetation, such as dense exotic grasses and thatch, which impedes their movements and foraging abilities.

Conceptual Basis for Model Development: Pacific kangaroo rats live in coastal sage scrub, chaparral, oak woodland, pinyon-juniper woodland, desert scrub, and annual grassland (Bleich and Price 1995, W. Spencer pers. comm.). They have also been recorded in alluvial fan sage scrub (Price et al. 1991) and montane coniferous forests (Sullivan and Best 1997). This species prefers more open areas and is particularly abundant in ecotonal habitats (Meserve 1976, M'Closkey 1976, Price and Kramer 1984, Keeley and Keeley 1988, Price et al. 1991, Goldingay and Price 1997).

Kangaroo rats can be quite mobile for rodents of their size when in their preferred, open habitats. Merriam's kangaroo rats, for example, typically remain within 1-2 territories (approximately 100 m [328 ft]) of their birthplace, but they are capable of dispersing more than a kilometer (Zeng and Brown 1987). Pacific kangaroo rats prefer to move through open habitat in early successional communities. They avoid roads, densely vegetated communities, and urban areas.

See Table 2 for model variable scorings for this species. Cost to movement for Pacific kangaroo rats was defined by weighting these inputs as follows:

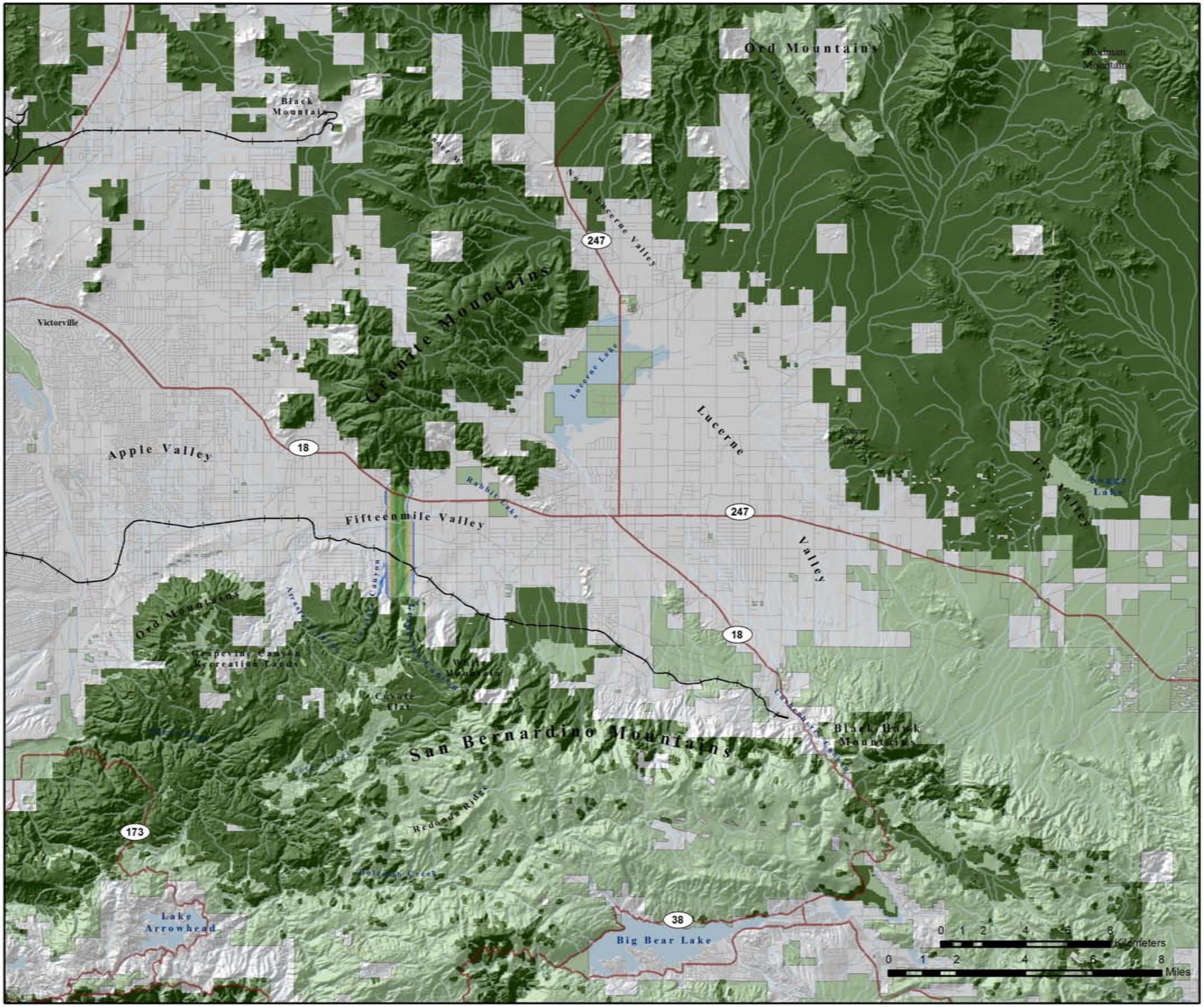
(Vegetation * 70%) + (Road Density * 10%) + (Topography * 10%) + (Elevation * 10%)

Results & Discussion: The least cost corridor for the Pacific kangaroo rat overlaps the most permeable paths for badger and bighorn sheep (Figure 12), ranging in width from 1 to 2 km (0.6 to 1.2 mi). However, there is also a narrow branch that extends from Lovelace Canyon in the San Bernardino Mountains for about 1 km before joining the primary corridor.

Figure 12.
Least Cost Corridor
for
Pacific kangaroo rat
(Dipodomys agilis)

Least Cost Corridor
- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Protected Lands
- Hydrography
- Roads
- Railroads

*This analysis was run from medium to high suitable habitat within targeted protected areas.



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Patch Size & Configuration Analyses

Although, the permeability models and Least Cost Union delineated areas of habitat that, based on model assumptions and available GIS data, are best suited to facilitate species movement between core habitat areas, they did not address whether suitable habitat in the Union occurs in large enough patches to support viable populations or whether patches are close enough together to allow for inter-patch dispersal. In addition, these preliminary results were based on only 3 of the thirteen modeled focal species. We therefore performed habitat suitability; patch size and configuration analyses to evaluate the configuration and extent of potentially suitable habitat in the Least Cost Union for all thirteen focal species. This helped determine whether there is sufficient habitat within the Union to support each species, and whether that habitat is distributed in a pattern that allows the species to move between patches.

Specifically, the patch size and configuration analysis for all thirteen focal species evaluated, (1) whether the Least Cost Union provides sufficient live-in or move-through habitat to support individuals or populations of the species; (2) whether these habitat patches are within the species' dispersal distance; (3) whether any clearly unsuitable and non-restorable habitat (e.g., developed land) should be deleted from the Union; and (4) for any species not adequately served by the Least Cost Union, whether expanding the Union to incorporate more habitat would meet the species' needs. The patch size and configuration analyses did not address existing barriers to movement (such as highways or railroads) or land use practices that may prevent species from moving through the linkage. These issues are addressed in the next section.

The Least Cost Union contains suitable habitat to support either inter- or intra-generational movements between the San Bernardino Mountains and the Granite, Ord, and Rodman mountain ranges for all of the focal species (American badger, Nelson's bighorn sheep, antelope ground squirrel, desert woodrat, Merriam's kangaroo rat, Pacific kangaroo rat, rock wren, cactus wren, speckled rattlesnake, metalmark butterfly, green hairstreak butterfly, and Joshua tree), except the tarantula hawk. However, the wide-ranging tarantula hawk is a terrestrial invertebrate that may occasionally move through the linkage when its nectar sources are in bloom.

The patch configuration analyses suggest that all suitable habitat patches identified for each focal species are within the species' dispersal distances and will thus likely accommodate their movements.

We eliminated some small areas from the western branch of the Least Cost Union that have already been converted to urban uses (Figure 13). These areas are considered stewardship zones, areas in the linkage already converted to rural residential or other such uses where land stewardship should be encouraged. We widened the eastern branch of the Union to 2 km wide in a constricted area to meet the defined minimum corridor width (Figure 13). This constricted area south of Highway 247 was too narrow to ensure movements of Nelson's bighorn sheep, for which this eastern branch was initially delineated. Widening this area of the linkage to a minimum of 2 km should ensure adequate functionality for various focal species in addition to bighorn sheep, including American badger, antelope ground squirrel, and desert woodrat, and will make the linkage more robust to edge effects.

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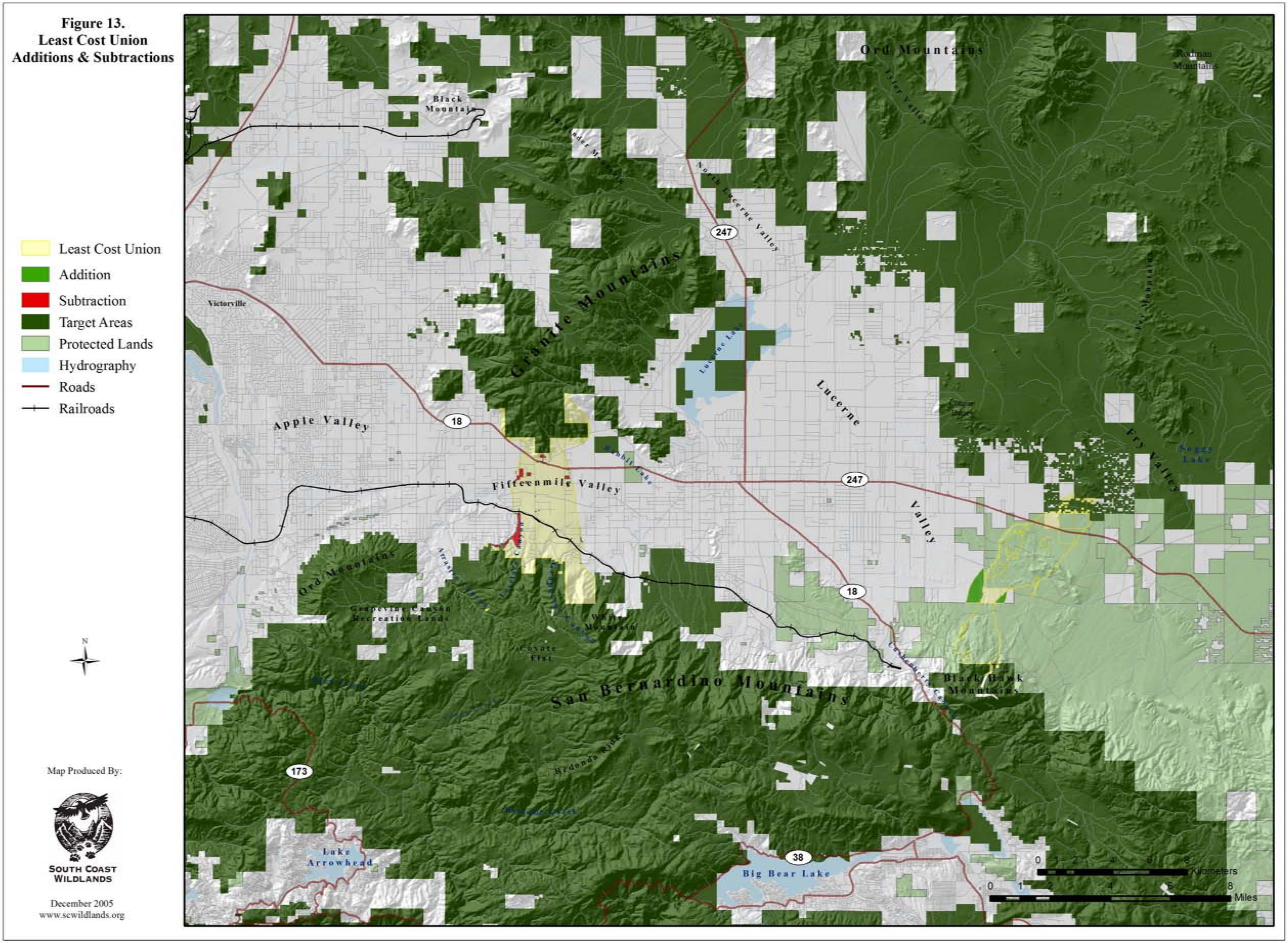
Figure 13.
Least Cost Union
Additions & Subtractions



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American badger (*Taxidea taxus*)

Distribution & Status: Once a fairly widespread resident in open habitats of California, the badger is now uncommon throughout the state and is considered a California Species of Special Concern (Zeiner et al. 1990, CDFG 1995).

Habitat Associations: Badgers are habitat specialists, associated with grasslands, prairies, and other open habitats (de Vos 1969, Banfield 1974, Sullivan 1996) but they may also be found in drier open stages of shrub and forest communities (Zeiner et al. 1990). They are known to inhabit forest and mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper, and sagebrush habitats (Long and Killingley 1983, Zeiner et al. 1990). They are occasionally found in open chaparral (< 50% cover) but have not been documented in mature stands of chaparral (Quinn 1990, Zeiner et al. 1990). Badgers prefer friable soils for excavating burrows and require abundant rodent populations (de Vos 1969, Banfield 1974, Sullivan 1996). The species is typically found at lower elevations (Zeiner et al. 1990) in flat, rolling, or steep terrain but they have been recorded at elevations up to 3,600 m (12,000 ft; Minta 1993).

Spatial Patterns: Home range sizes for this species vary both geographically and seasonally. Depending on location, male home ranges have been estimated to vary from 240-850 ha (593-2,100 ac) while females ranged from 137-725 ha (339-1,792 ac; Long 1973, Lindzey 1978, Messick and Hornocker 1981, Zeiner et al. 1990). In northwestern Wyoming, home ranges up to 2,100 ha (5,189 ac) have been reported (Minta 1993). In Idaho, home ranges of adult females and males averaged 160 ha (395 ac) and 240 ha (593 ac), respectively (Messick and Hornocker 1981). In Minnesota, Sargeant and Warner (1972) radio-collared a female badger whose overall home range encompassed 850 ha (2,100 ac). However, her home range was restricted to 725 ha (1,792 ac) in summer, 53 ha (131 ac) in autumn and to a mere 2 ha (5 ac) in winter. In Utah, Lindzey (1978) found fall and winter home ranges of females varied from 137-304 ha (339-751 ac), while males varied from 537-627 ha (1,327-1,549 ac; Lindzey 1978). Males may double movement rates and expand their home ranges during the breeding season to maximize encounters with females (Minta 1993). Lindzey (1978) documented natal dispersal distance for one male at 110 km (68 mi) and one female at 51 km (32 mi).

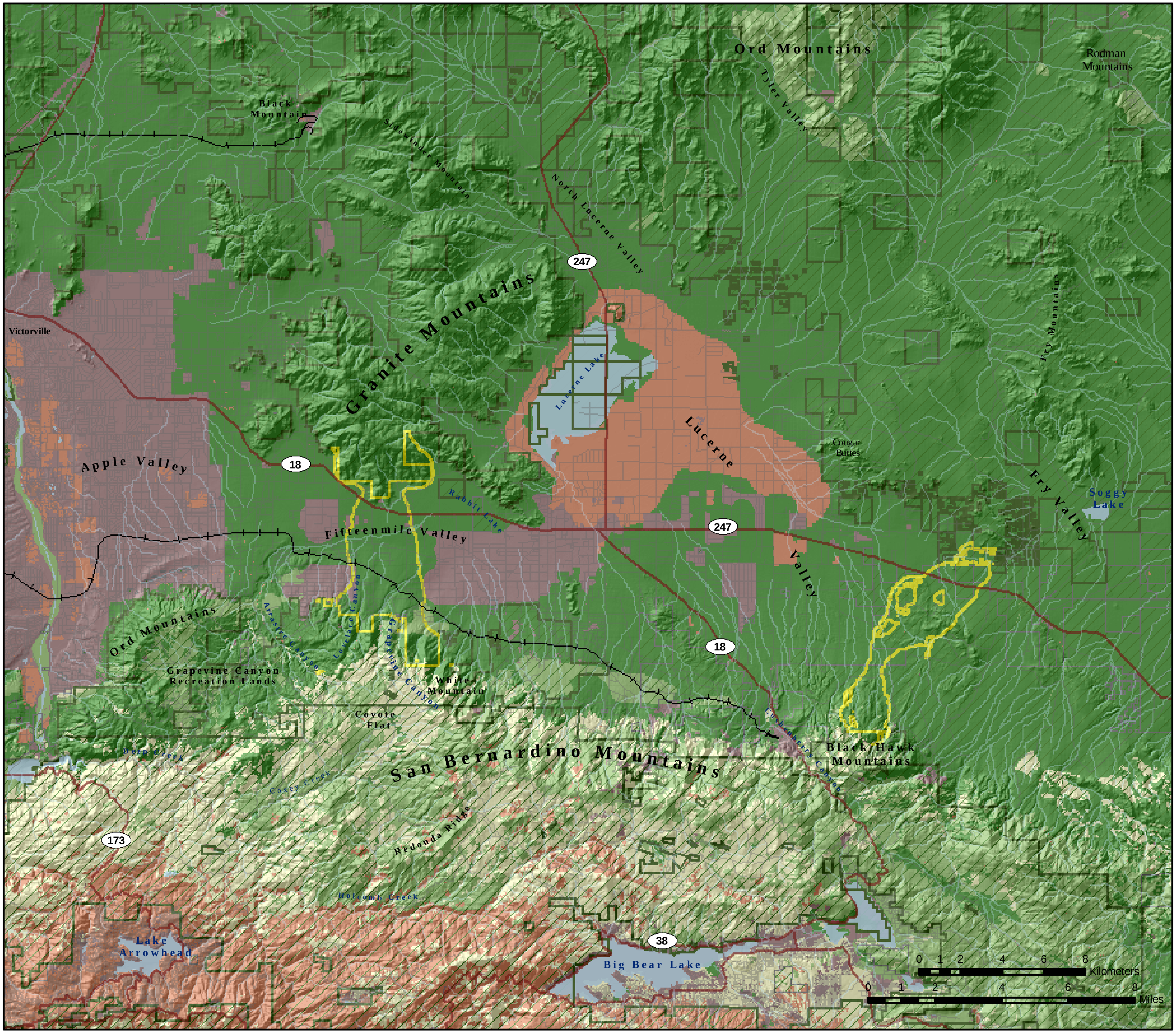
Conceptual Basis for Model Development: Badgers prefer grasslands, meadows, open scrub, desert washes, and open woodland communities. Terrain may be flat, rolling or steep, but below 3,600 m elevation. Core areas capable of supporting 50 badgers are equal to or greater than 16,000 ha (39,537 ac). Patch size is $\geq$ 400 ha (988 ac) but < 16,000 ha. Dispersal distance for badgers was defined as 220 km (136 mi), twice the longest recorded dispersal distance (Lindzey 1978).

Results & Discussion: The model identified abundant suitable badger habitat in the planning area, with the most highly suitable contiguous habitat extending from the desert slopes of the San Bernardino Mountains, through both branches of the Least Cost Union, to protected lands in the Granite, Ord, and Rodman Mountains (Figure 14). The least cost corridor for badger (Figure 10) followed the western branch of the Union, though both branches of the Union encompass the gently sloping and relatively flat topography that is preferred by this species. The majority of suitable habitat within the planning area is contiguous, and thus was identified as core habitat (Figure 15). All potential suitable habitat is within badger's dispersal distance (figure not shown), although barriers to movement may exist between suitable habitat patches. We conclude that the linkage is likely to serve the movement needs of this wide-ranging species.

Roadkill is a leading cause of death in badgers. To restore and protect habitat connections for badger, we recommend that:

- Badger tunnels or pipe culverts be installed under State Highways 18 and 247 during the next transportation improvement projects for these roads.
- No additional roads are built across the linkage.
- Lighting is directed away from the linkage and crossing structures.
- Standard wildlife crossing signs or dynamic signs linked to infrared or laser sensors are installed to alert drivers to reduce speed while traveling through the linkage to minimize wildlife/vehicle collisions.

Figure 14.
Habitat Suitability for American badger
(Taxidea taxus)



Degree of Suitability
- High
- Medium to High
- Medium
- Low to Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

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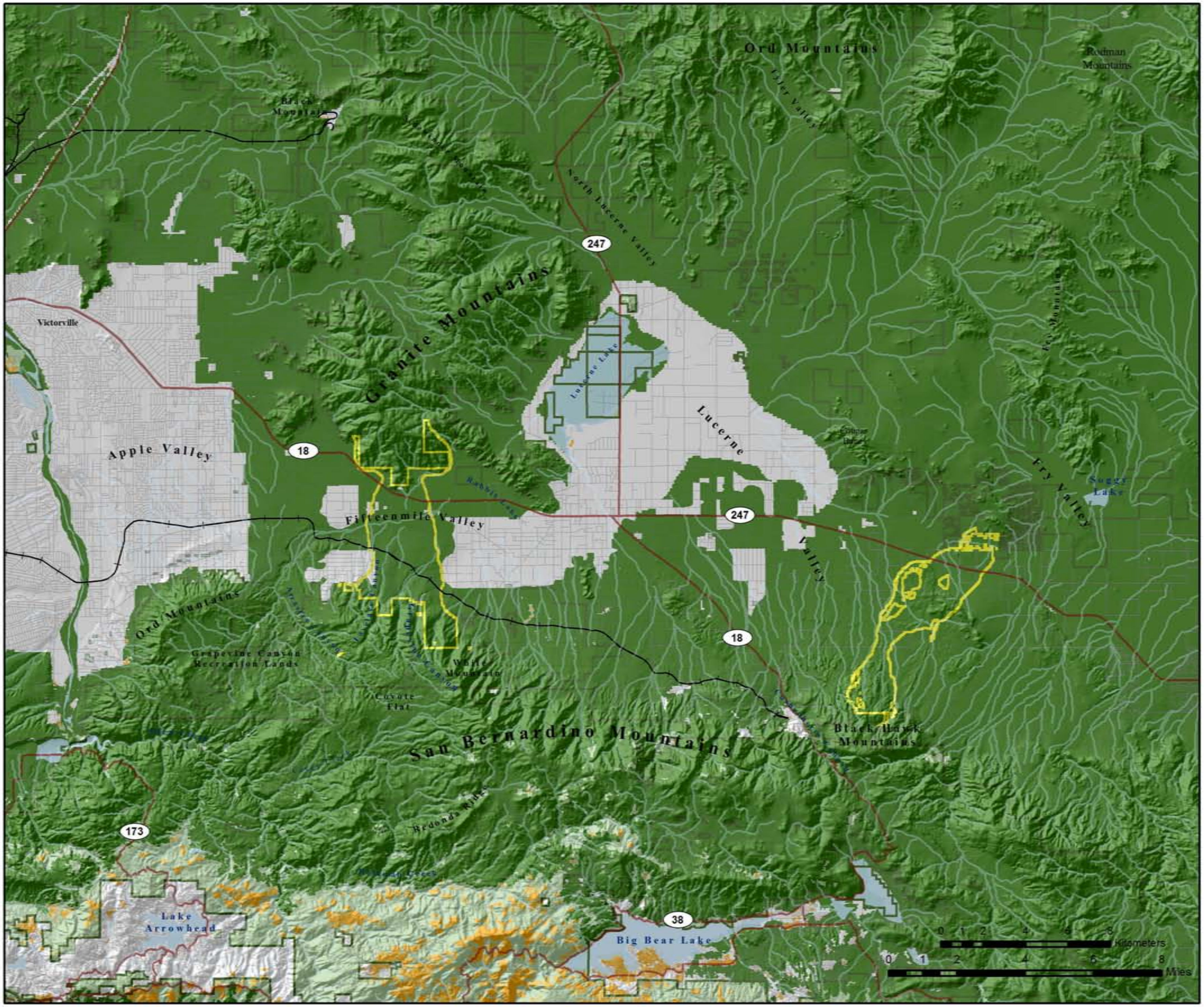
Figure 15.
Potential Cores & Patches for American badger
(Taxidea taxus)

- Core
- Patch
- < Patch
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads



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Nelson's bighorn sheep (*Ovis canadensis nelsoni*)

Distribution & Status: Bighorn sheep were previously divided into seven subspecies (Manville 1980). One subspecies has gone extinct while two others were combined (Manville 1980). In California, Nelson's bighorn sheep inhabit mountain ranges from the White Mountains to the southern Sierra Madre Range, San Gabriel, San Bernardino Mountains, and Little San Bernardino Mountains, and south to the Mexican border (CDFG 1983, USFS 2002), typically between 914-3,068 m (3,000-10,064 ft) elevation (Holl and Bleich 1983, USFS 2002).

Bighorn populations have declined substantially and are now considered one of the rarest ungulates on the continent (Seton 1929, Valdez and Krausman 1999, Krausman 2000). Major factors in the decline are disease (Cowan 1940, Buechner 1960, Wishart 1978, Monson 1980, Holl and Bleich 1983, Thorne et al. 1985, Singer et al. 2000a), lion predation (Hayes et al. 2000, USFWS 2000), habitat loss, degradation, and fragmentation due to urbanization, mining, roads, and recreational activities (Light et al. 1967, Graham 1971, Light and Weaver 1973, Jorgensen 1974, DeForge 1980, Wilson et al. 1980, Holl and Bleich 1983, Krausman et al. 1989, Ebert and Douglas 1993, Stephenson and Calcarone 1999, USFWS 2000, Krausman et al. 2000, Papouchis et al. 2001), livestock grazing, hunting, and loss of water sources (Beuchner 1960, Bailey 1980, Graham 1980, McCutcheon 1981, Bailey 1984, Geist 1985). Nelson's bighorn sheep are listed as a Sensitive Species by the USFS and the BLM and are identified as a Management Indicator Species in the San Bernardino National Forest's Land and Resource Management Plan (Holl et al. 2004). Nelson's bighorn is classified by CDFG as a big game animal.

Habitat Associations: Bighorn sheep are habitat specialists that prefer open habitats in steep rocky terrain (Van Dyke et al. 1983, Risenhoover et al. 1988, Smith et al. 1991, Singer et al. 2000). Escape terrain is identified as the single most important habitat component (Buechner 1960, Welch 1969, Shannon et al. 1975, Hudson et al. 1976, Sandoval 1979, McCullough 1980, Tilton and Willard 1982, Holl and Bleich 1983, Van Dyke et al. 1983, Hurley and Irwin 1986, Bentz and Woodard 1988, Smith and Flinders 1991, Smith et al. 1991, Singer et al. 2000a, Singer et al. 2000b, Zeigenfuss et al. 2000, USFWS 2000, USFS 2002, Holl et al. 2004).

Provided there is sufficient steep, rocky terrain, desert bighorn sheep may utilize a variety of vegetation communities, including alpine dwarf shrub, low sage, sagebrush, pinyon-juniper, palm oasis, desert riparian, desert scrub, subalpine conifer, perennial grassland, and montane riparian (Krausman et al. 1999). In addition, bighorn sheep in the San Gabriel Mountains utilize montane chaparral, oak, and conifer habitats more than bighorn sheep in other populations do (Holl and Bleich 1983). They remain near water during summer (Leslie and Douglas 1979, Monson 1980, Wehausen 1980, Tilton and Willard 1982, Wehausen 1983, CDFG 1983) and, in the San Gabriel Mountains, use mineral licks seasonally (April to September) to supplement their dietary requirement for sodium (Holl and Bleich 1983). The young learn about escape terrain, water sources, and lambing habitat from elders (USFWS 2000, USFS 2002).

Spatial Patterns: Bighorn sheep distribution is associated with mountainous habitat and proximity to escape terrain, often defined as steep and rugged slopes, which are important habitat attributes (Tilton and Willard 1982, Smith and Flinders 1991, Singer et al. 2000b). Although definitions of escape terrain vary considerably (USFWS 2000), Holl and Bleich (1983) defined escape terrain for bighorn sheep in the San Gabriel Mountains as slopes greater than 80 degrees with rock outcrops. Holl and Bleich (1983) reported that bighorn sheep also use slopes less than 20 degrees when crossing a canyon bottom or drinking from a stream.

In some mountain ranges, bighorn sheep make seasonal movements between winter and summer ranges, spending summer at higher elevation and moving down slope in winter (USFWS 2000).

Females form ewe groups and have small home ranges, while rams roam over larger areas, moving among ewe groups (Geist 1971). Nelson's bighorn sheep in the San Gabriel Mountains were found to have fairly small home ranges: 5 ewes averaged 3.9 km^2 (1.5 mi^2), while one adult ram had a home range of 17.9 km^2 (6.9 mi^2; DeForge 1980, Holl et al. 2004). Home ranges of bighorn sheep in the Peninsular Ranges were found to average 25.5 km^2 (9.8 mi^2) for rams and 20.1 km^2 (7.8 mi^2) for ewes (DeForge et al. 1997, USFWS 2000). Rubin et al. (2002) reported mean female home range sizes of 23.9 km^2 (9.2 mi^2) and 15 km^2 (5.8 mi^2) when using adaptive kernel and minimum convex polygon methods, respectively, in the Peninsular Ranges. Another study, conducted in Colorado, found much larger home range sizes, with rams ranging from 9.8-54.7 km^2 (3.8-21.1 mi^2) and ewes ranging from 6.1–35.3 km^2 (2.4-13.6 mi^2; Singer et al. 2001).

The longest recorded movement of a ewe is 30 km (18.6 mi), although analyses of genetic data suggest that movement of ewes among groups is rare (USFWS 2000, USFS 2002). Bleich et al. (1996) reported one case of a ewe emigrating and reproducing in a new mountain range, while McQuivey (1978) reported 4 such movements by ewes. Genetic analyses indicated more frequent movements by males than by females (USFWS 2000, USFS 2002). A Canadian study (Blood 1963) estimated rams moved approximately 24 km (14.9 mi). Geist (1971) observed ram movements up to 35 km (21.7 mi). Witham and Smith (1979) documented a ram moving 56 km (34.8 mi). DeForge (1980) reported a ram moving approximately 10 km (6.2 mi) in the San Gabriel Mountains.

Conceptual Basis for Model Development: Numerous habitat suitability models have been developed for bighorn sheep (Buechner 1960, Hansen 1980, Holl 1982, Van Dyke et al. 1983, Risenhoover and Bailey 1985, Hurley and Irwin 1986, Bentz and Woodard 1988, Armentrout and Brigham 1988, Cunningham 1989, Smith et al. 1991, Singer et al. 2000, Zeigenfuss et al. 2000); however, applying the results of such models outside of the original study areas may result in spurious results (Andrew et al. 1999).

We delineated potentially suitable habitat as escape terrain (slopes 27-85 degrees) and adjacent flat areas that were less than 300 m (984 ft) from escape terrain (Buechner 1960, Van Dyke et al. 1983, Hurley and Irwin 1986, Bentz and Woodard 1988, Singer et al. 2000b). Four other criteria were used to remove areas of unsuitable habitat from this layer: 1) areas with dense vegetation (i.e., poor visibility) (Risenhoover and Bailey 1985, Singer et al. 2000b, Zeigenfuss et al. 2000); 2) areas too far from perennial streams and springs (>3.2 km; 2 mi; Singer et al. 2000b, Zeigenfuss et al. 2000); 3) areas within 150 m (492 ft) of development (Smith et al. 1991, Singer et al. 2000b, Zeigenfuss et al. 2000); and 4) habitat patches below 1,000 m (3,218 ft) in elevation (Holl and Bleich 1983).

Core areas were delineated after Singer et al. (2000b) as areas of suitable habitat greater than or equal to 17 km^2 (4,201 ac). Patches were defined as $\geq$ 3.9 km^2 (963 ac) but less than 17 km^2. Dispersal distance for bighorn sheep was defined as 20 km (12 mi), twice the distance recorded for a ram in the San Gabriel Mountains.

Results & Discussion: The output provided by the habitat suitability analysis corresponds with important habitat areas identified for this species (Stephenson and Calcarone 1999, USFS 2002, BLM 2002, 2003, 2005). Both branches of the Least Cost Union were delineated by the landscape permeability analysis for bighorn sheep (Figure 11), though neither contains a significant amount of suitable habitat (Figure16). However, as stated in the West Mojave Plan Proposed Conservation Strategy (BLM 2002), maintaining the San Bernardino to Granite Mountains linkage “would conserve an occupied linkage for bighorn sheep”. The patch size analysis identified potential core areas and patches of suitable habitat in all targeted mountain ranges (Figure 17) that largely overlap with areas utilized by bighorn sheep. The model captured habitat in the San Bernardino Mountains, including the largest population on San Gorgonio Mountain and the Cushenbury population on the northern edge of the range in desert-facing canyons (Stephenson and Calcarone 1999, USFS 2002, S. Loe, pers. com.). All potential habitat linking core areas and patches are within the species’ dispersal distance (figure not shown), though barriers to movement may exist between areas of suitable habitat. Both branches of the Least Cost Union are likely to serve this species.

Bighorn sheep avoid heavily used roads (Jorgensen 1974, Wilson et al. 1980, Krausman et al. 1989, Ebert and Douglas 1993, Rubin et al. 1998, Papouchis et al. 2001), although females will cross roads on rare occasions and rams cross roads more frequently (Rubin et al. 1998). MacArthur et al. (1982) concluded that well designed transportation systems could minimize disturbance to sheep (Holl and Bleich 1983).

The Enhanced Ecosystem Protection Alternative of the Draft Environmental Impact Report and Statement for the West Mojave Plan (BLM 2003) would have provided for the retention of this linkage. However, under the Proposed Action of the West Mojave Plan the linkage “would not be conserved unless additional data proving bighorn dispersal is gathered” (BLM 2005). To restore and protect habitat connections for bighorn sheep moving between the San Bernardino Mountains and the Granite, Ord, and Rodman Mountains, we recommend that:

- Bighorn sheep be radio-collared to determine movement patterns in this area (Holl et al. 2004).

Figure 16.
Potential Habitat
for
Nelson's bighorn sheep

(Ovis canadensis nelsoni)

- Potential Habitat
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

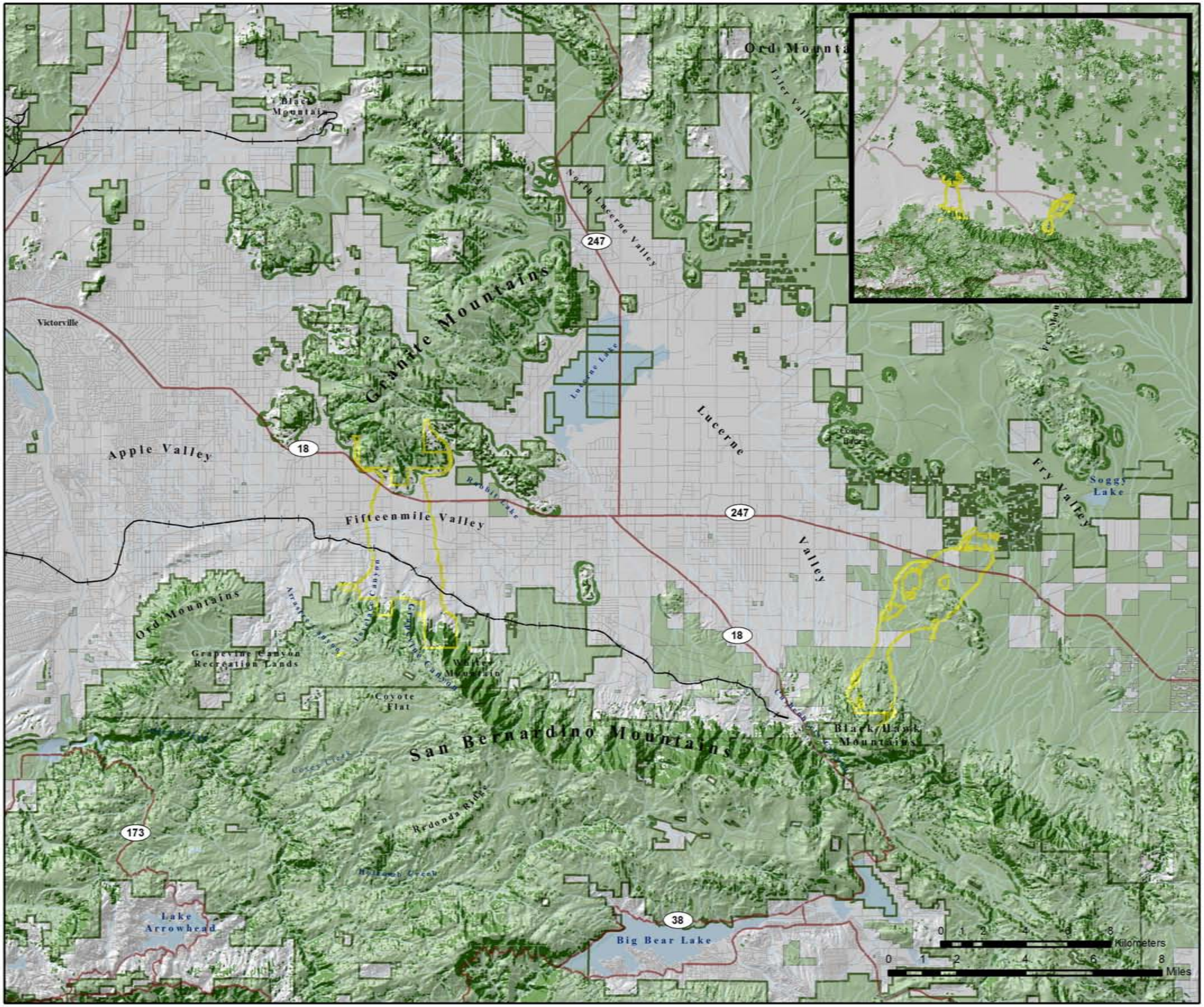

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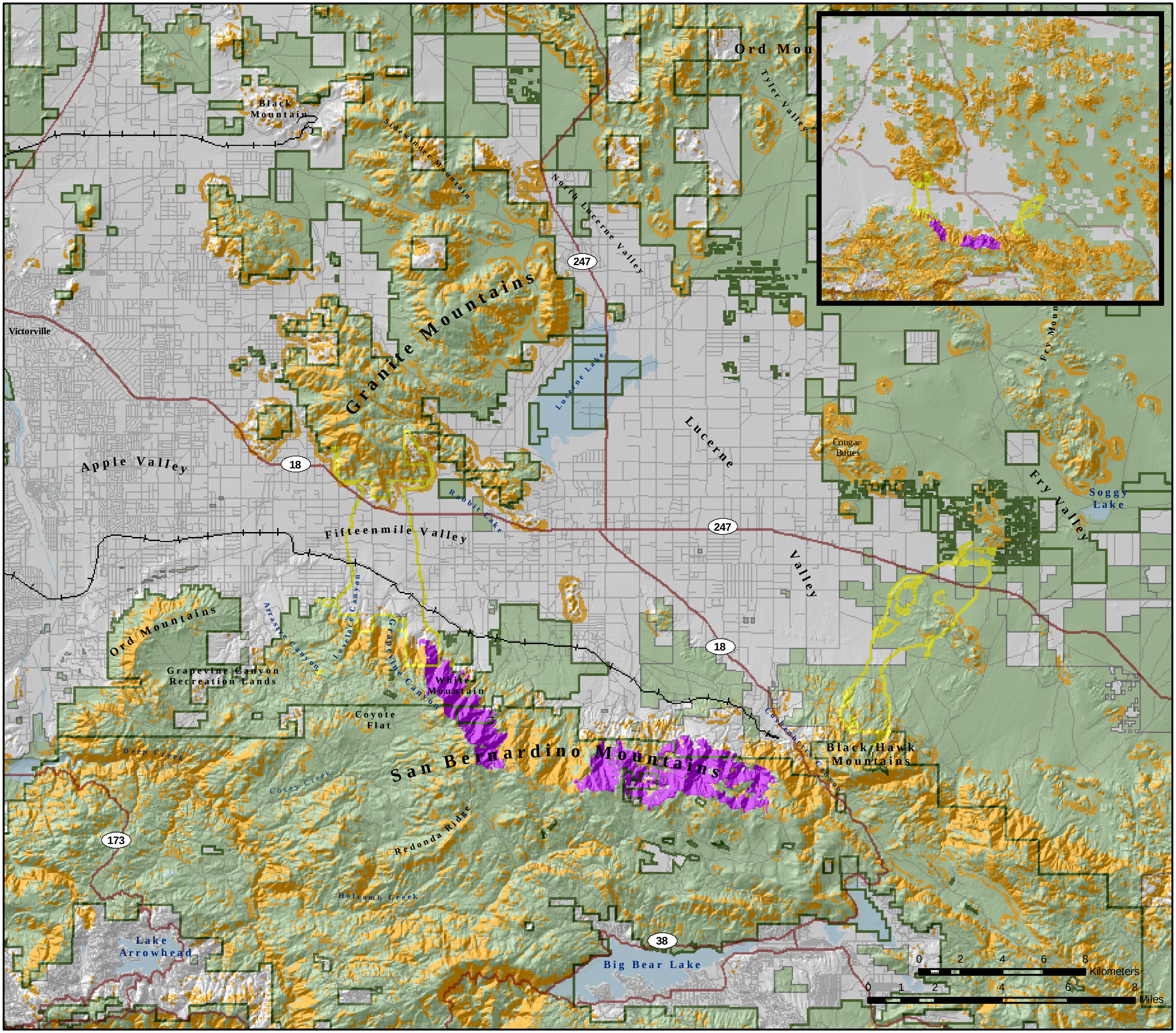
Figure 17.
Potential Cores & Patches for Nelson's bighorn sheep
(Ovis canadensis nelsoni)



- Patch
- < Patch
- Least Cost Union
- Target Areas
- Protected Lands
- Lakes & Reservoirs
- Roads
- Railroads

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- No new roads should be constructed in occupied or potential habitat (USFWS 2001).

- No new roads or trails should pass within 100 m of a mineral lick or water source (Holl and Bleich 1983, E. Rubin pers. com.), established roads or trails should be seasonally closed (April-September).

- Roads and trails that pass through known lambing areas should be closed during the reproductive season (Holl and Bleich 1983, Papouchis et al. 2001, USFWS 2000, USFWS 2001).

- Off-road vehicles be excluded from occupied and historic habitat (USFWS 2000, USFWS 2001); closures should be enforced.

- Leash laws are enforced so that dogs are under restraint at all times (USFWS 2000, USFWS 2001, Holl et al. 2004).

- USFS, BLM, CDFG and the Counties should continue to control feral dogs and dogs allowed to run loose from surrounding communities.

- Domestic sheep and goats are prohibited within 9 miles of bighorn habitat to reduce the potential for disease transmission (USFWS 2000, USFWS 2001, Holl et al. 2004).

- The CalTIP (Californians Turn in Poachers) program's toll free reporting number (800-952-5400) be widely publicized (Anonymous 1984).

- Critical parcels are protected through conservation agreements, acquisition, fee title agreements, etc.

Antelope ground squirrel (*Ammospermophilus leucurus*)

Justification for Selection: The antelope ground squirrel may be a keystone species because its burrows are used by a wide variety of wildlife, including reptiles, insects, and other rodents.

Distribution & Status: Members of the genus *Ammospermophilus* are found in the xeric desert habitats of the southwestern United States and northern Mexico (USFWS 1998, USFS 2002). The antelope ground squirrel is one of five species in the genus (Best et al. 1990, USFS 2002). It is common to abundant in the Great Basin, Mohave, and Colorado deserts of California south to the Mexican border (Miller and Stebbins 1964, Ingles 1965, Bradley and Mauer 1973, Honeycutt et al. 1981, Jameson and Peeters 1988, Zeiner et al. 1990).

Habitat Associations: The most favorable habitats for the antelope ground squirrel are desert scrubs, sagebrush, bitterbrush, and Joshua tree and pinyon-juniper woodlands. They may also be found in desert riparian and desert wash habitats and to a lesser extent in mixed chaparral and annual grassland (Miller and Stebbins 1964, Ingles 1965, Bradley and Mauer 1973, Honeycutt et al. 1981, Zeiner et al. 1990). This species has lower water and energy requirements than non-desert mammals of similar size; their ability to obtain succulent plant or animal foods throughout the year appears to be their primary survival tool (Nagy 1994). Friable soil for burrowing is a habitat requisite, as burrows are used to escape predators and severe temperatures in the desert environment (Grinnell and Dixon 1919, Bartholomew and Hudson 1961, Bradley 1967, Zeiner et al. 1990). Individuals may utilize numerous burrows within their home range.

Spatial Patterns: In Nevada, home range sizes varied from 1.4-9.4 ha (3-20.6 ac) (Allred and Beck 1963, Bradley 1967, Zeiner et al. 1990), with an average of 6.7 ha (14.8 ac; Allred and Beck 1963, Zeiner et al. 1990). Evidently, the antelope ground squirrel is non-territorial (Fisler 1976, 1977, Zeiner et al. 1990), although they occur widely scattered and not clustered in colonies (Jameson and Peeters 1988). No dispersal estimates were found for this species in the literature, though they can home from distances up to 1.6 km (1 mi; Bradley 1968, Zeiner et al. 1990).

Conceptual Basis for Model Development: Movement in the linkage is assumed to occur over multiple generations. The antelope ground squirrel is restricted to arid desert habitats. Potential core areas were identified as greater than or equal to 168 ha (415 ac). Patch size was classified as $\geq$ 3 ha (7.41 ac) but less than 168 ha. Dispersal distance was defined as 3.2 km (1.9 mi).

Results & Discussion: Extensive suitable habitat was identified for this species in the desert mountain ranges and on the desert-facing slopes of the San Bernardino Mountains; both branches of the Least Cost Union contain highly suitable habitat for this species (Figure 18). The majority of suitable habitat was identified as potential core areas for this species (Figure 19). All potential cores and patches of suitable habitat are within the defined dispersal distance for this species (figure not shown), although barriers to movement may exist between suitable habitat patches. The linkage will likely serve the needs of antelope ground squirrels.

To protect and restore habitat for antelope ground squirrel, we recommend adding crossing structures for small mammals fairly frequently to facilitate movement across State Highways 18 and 247, and reduce roadkill.

Figure 18.
Habitat Suitability
for
Antelope ground squirrel
(Ammospermophilus leucurus)

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

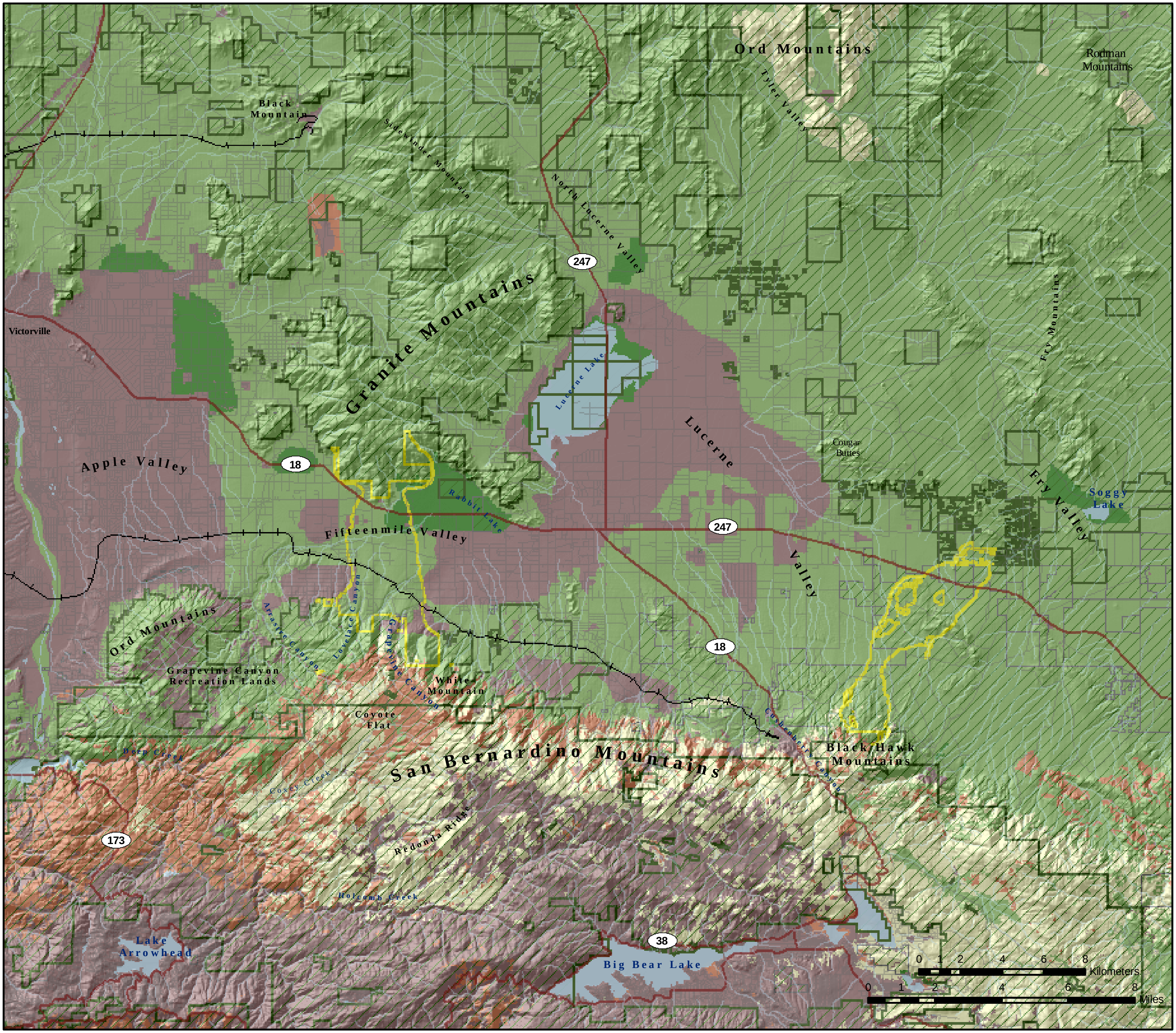

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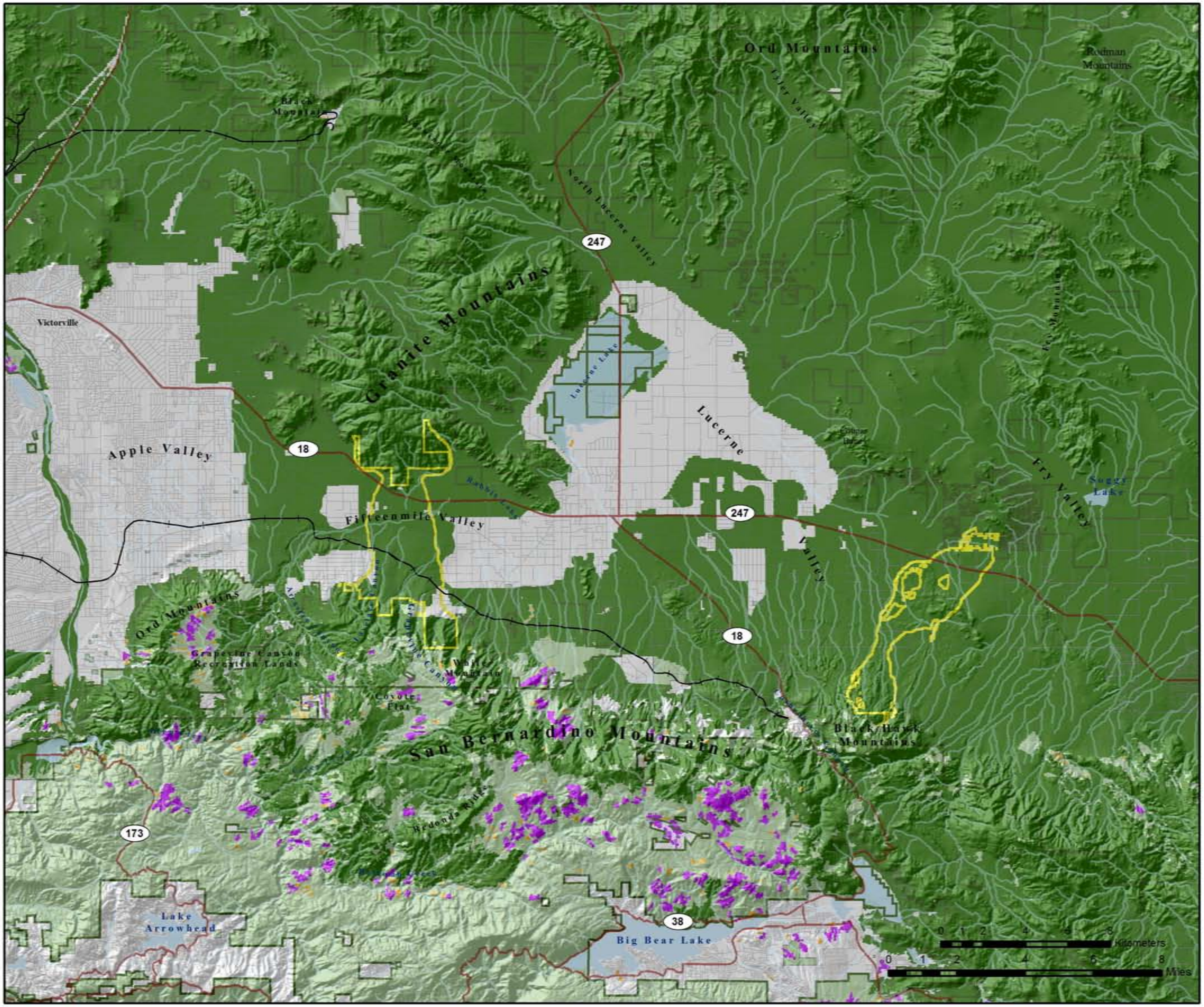
Figure 19.
Potential Cores & Patches for Antelope ground squirrel
(Ammospermophilus leucurus)



Core
Patch
< Patch
Least Cost Union
Target Areas
Protected Lands
Hydrography
Roads
Railroads

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Desert woodrat (*Neotoma lepida*)

Justification for Selection: This species is sensitive to habitat fragmentation, particularly in riparian systems.

Distribution & Status: *Neotoma lepida* inhabits virtually all of southern California, with a range extending northward along the coast to the San Francisco Bay area and inland from Inyo County south throughout the Mojave Desert and from north-central Tulare County south through the Tehachapi and San Bernardino Mountains. They also occur in extreme northeastern California, on the Baja California peninsula in Mexico, and on several islands in the Gulf of California and the Pacific Ocean near Baja, as well as in southeastern Oregon, southwestern Idaho, Nevada, and western Utah (Zeiner et al. 1990, Verts and Carraway 2002). There are 23 subspecies, *N. l. lepida* occurs in the study area. They are typically associated with elevations below 2,900 m (9,514 ft) in California (Verts and Carraway 2002).

Habitat Associations: Desert woodrats may be found in sagebrush, chaparral, Joshua tree woodland, scrub oak woodland, pinyon-juniper woodland, riparian zones, creosote bush scrub, desert scrub and rocky slopes with scattered cactus, yucca, pine-juniper, and other low vegetation, and occasionally in salt marsh habitats (Zeiner et al. 1990, Verts and Carraway 2002). They are common to abundant in Joshua tree woodland, pinyon-juniper woodland, mixed and chamise-redshank chaparral, sagebrush, and most desert habitats, reaching their highest densities in rocky areas with Joshua trees (Lee 1963, MacMillen 1964). Woodrats are known for their large, multichambered dwellings, which they depend upon for shelter, storing food items, and refuge from predators (Carraway and Verts 1991, Matocq 2002). Desert woodrats occupy elaborate dens built of vegetative debris among cacti or yucca, along cliffs, among rocks, and occasionally in trees (Lee 1963, MacMillen 1964). Thompson (1982) observed desert woodrats actively avoiding open areas that did not provide adequate refuge sites. They are largely dependent upon prickly pear for water balance in desert habitats, although they can be sustained on creosote year-round (Lee 1963, MacMillen 1964).

Spatial Patterns: In the Little San Bernardino Mountains, Thompson (1982) reported the average home range of desert woodrats to be 0.05 ha (0.13 ac), which generally included one diurnal den and foraging habitat. In coastal sage scrub, home range has been reported to range from 0.04 to 0.2 ha (0.1 to 0.5 ac) (MacMillen 1964, Bleich and Schwartz 1975). Populations may be limited by the availability of nest-building materials (Linsdale and Tevis 1951, Brylski 1990).

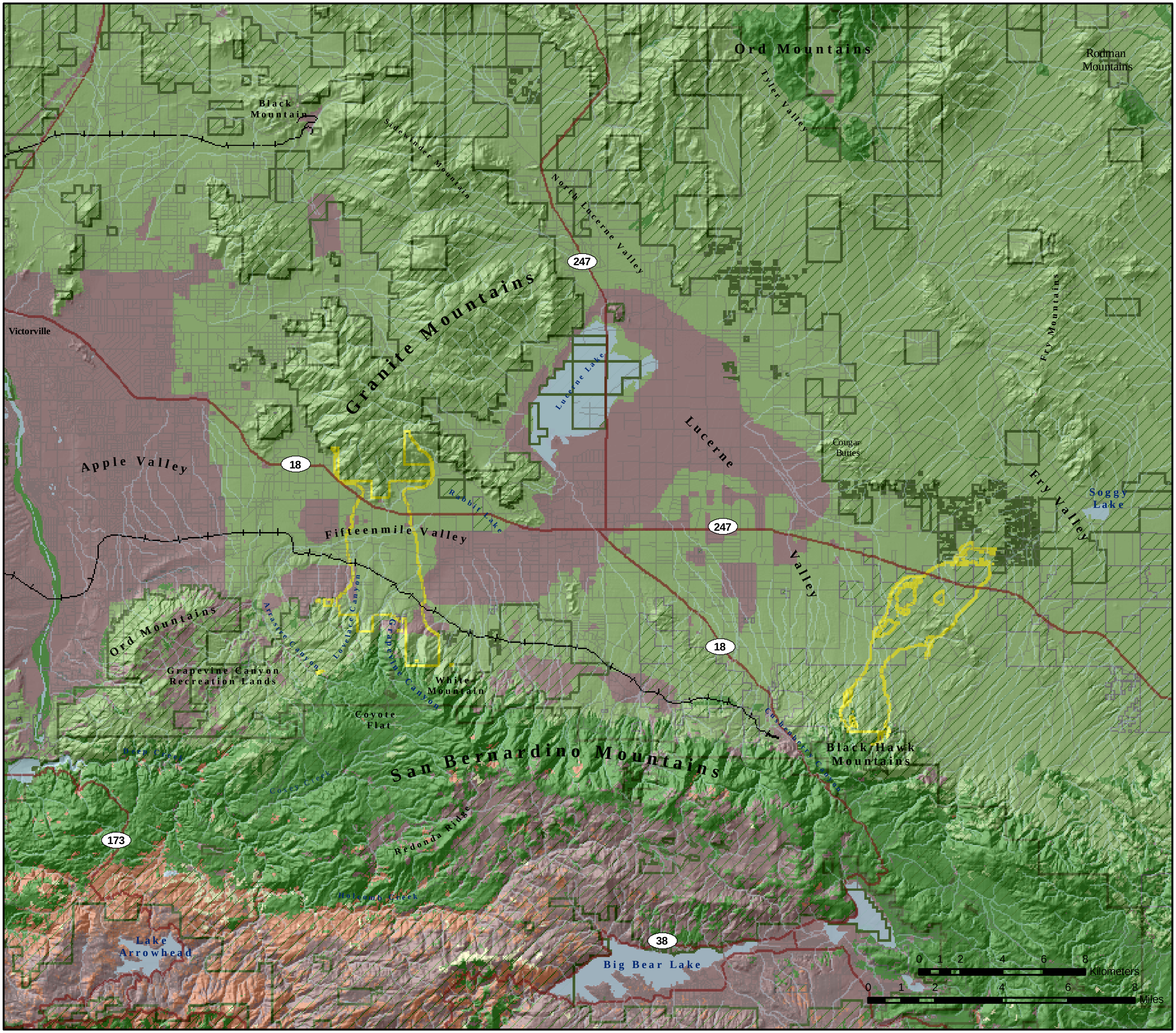
Natal site dispersal in the eastern Mojave Desert appears to be greater for male desert woodrats. Average linear movements were about 14 m (46 ft) per night. In sagebrush-juniper habitat, males moved an average of 80 m (262 ft) per night, while female movements averaged 45 m (147 ft) (Stones and Hayward 1968).

Conceptual Basis for Model Development: Movement in the linkage is assumed to be multigenerational. Desert woodrats are associated with Joshua tree woodland, pinyon-juniper woodland, chaparral, sagebrush, and most desert habitats, and are typically found below 2,900 m elevation. Core areas were defined as $\geq$ 3 ha (7.41 ac). Patch size was defined as $\geq$ 0.1 ha (0.25 ac) and < 3 ha. Dispersal distance was defined as 160 m (524 ft).

Results & Discussion: Potential habitat for the desert woodrat is widespread in the planning area, with both branches of the Least Cost Union containing highly suitable habitat for this species (Figure 20). The majority of suitable habitat was identified as potential cores areas with smaller patches identified at higher elevations in the San Bernardino Mountains (Figure 21). All potential core areas and patches of suitable habitat are within the defined dispersal distance of the woodrat (figure not shown), though barriers to movement may exist between suitable habitat patches. We conclude that the linkage is likely to serve the needs of this species for movement among populations. To protect and restore habitat connectivity for the desert woodrat, we recommend that:

- Crossing structures for small mammals be placed fairly frequently to facilitate movement across major transportation routes.
- Lighting is directed away from the linkage and crossing structures.
- Local residents are informed about the proper use of rodenticides and pesticides to reduce the likelihood of ingestion of these lethal substances on small mammals indigenous to the area.

Figure 20.
Habitat Suitability
for
Desert woodrat
(Neotoma lepida)



Degree of Suitability

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

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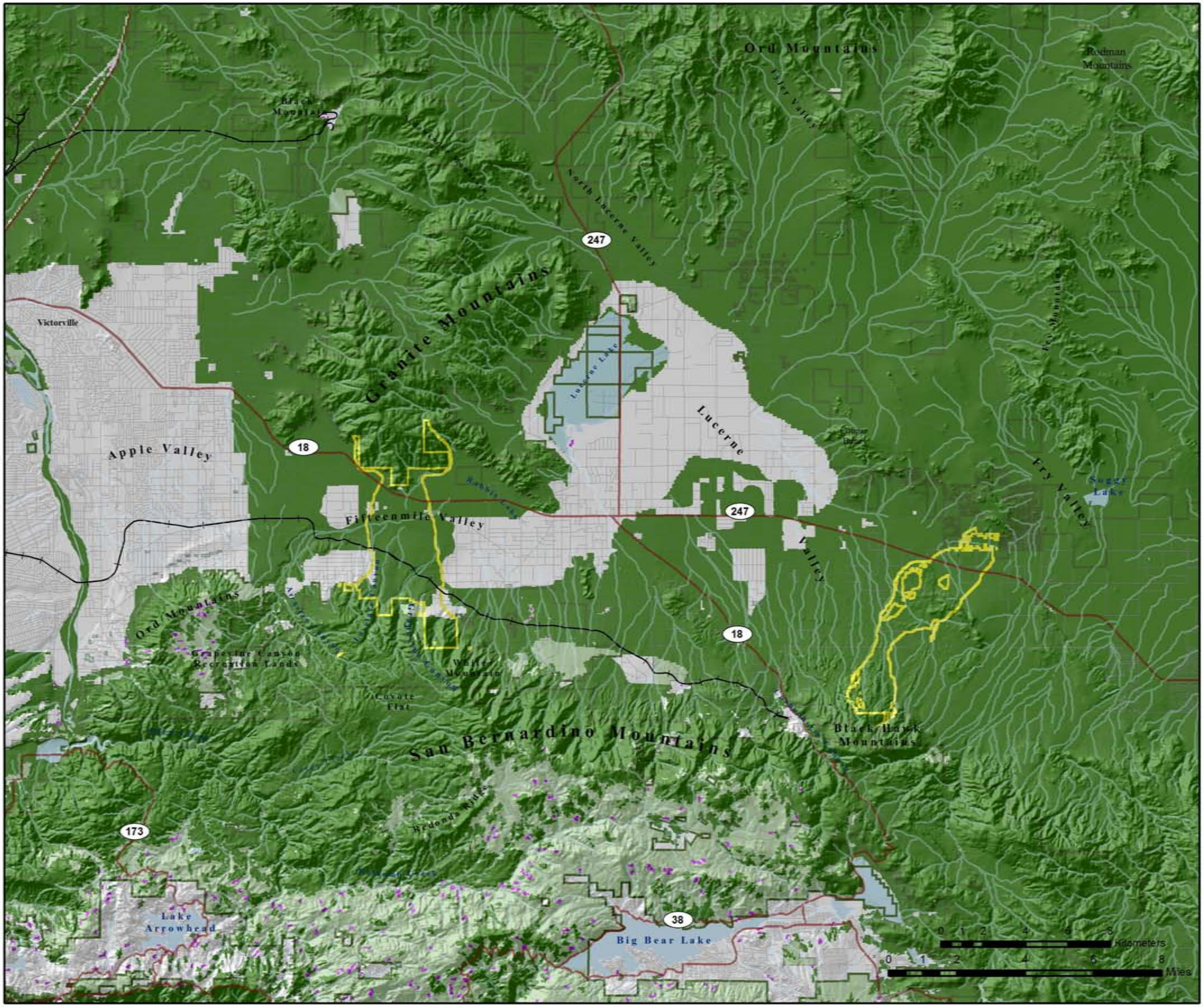
Figure 21.
Potential Cores & Patches for Desert woodrat
(Neotoma lepida)



- Core
- Patch
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

N

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Merriam's kangaroo rat (*Dipodomys merriami merriami*)

Justification for Selection: Merriam's kangaroo rat is sensitive to barriers, artificial light pollution, and dense stands of non-native annual grasses.

Distribution & Status: Merriam's kangaroo rat is a widespread species throughout arid regions of the western United States and northwestern Mexico (Hall and Kelson 1959, Williams et al. 1993, USFWS 1998). Three subspecies occur in southern California: *D. merriami merriami*, *D. m. collinus*, and *D. m. parvus*. *D. merriami merriami* occurs in the planning area; it is the most widespread kangaroo rat in California.

Merriam's kangaroo rat is not a special status species, but a subspecies not in this study area, *D. m. parvus* (San Bernardino kangaroo rat), was listed as endangered in 1998 (USFWS 1998).

Habitat Associations: Merriam's kangaroo rat occupies desert scrub habitats, sagebrush, Joshua tree, and pinyon-juniper habitats (Zeiner et al. 1990). They dwell in relatively flat or gently sloping areas with sparse to moderate vegetative cover (Zeiner et al. 1990). Merriam's kangaroo rat prefers sandy soils but they will also utilize rocky flats if they can excavate a burrow (Jameson and Peeters 1988, Zeiner et al. 1990).

Spatial Patterns: In the Palm Springs area, Merriam's kangaroo rat home range size averaged 0.33 ha (0.8 ac) for males and 0.31 ha (0.77 ac) for females (Behrends et al. 1986). Much larger home range sizes were documented for this species in New Mexico (Blair 1943), where home range size averaged 1.7 ha (4.1 ac) for males and 1.6 ha (3.8 ac) for females (USFWS 1998). Adults are territorial, defending areas surrounding their burrows (Jones 1993). Male and female home ranges overlap extensively but female home ranges rarely overlap (Jones 1989, USFWS 1998).

Merriam's kangaroo rat typically remains within 1-2 territories (approximately 100 m [328 ft]) of their birthplace, but the species is capable of longer dispersal (Jones 1989). Behrends et al. (1986) found movements of about 10 to 29 m (33-95 ft) between successive hourly radio fixes, but kangaroo rats are capable of moving much greater distances. For example, Daly et al. (1992) observed individuals moving as much as 100 m in a few minutes to obtain and cache experimentally offered seeds. Dispersal distances of up to 384 m (1,260 ft) have been recorded in Arizona (Zeng and Brown 1987).

Conceptual Basis for Model Development: Movement in the linkage is assumed to be multigenerational. Merriam's kangaroo rat prefers desert scrub, alkali desert scrub, sagebrush, creosote scrub, Joshua tree, and pinyon-juniper habitats. Within these habitats, they occupy flat and gently sloping terrain. Core areas were defined as ≥ 43 ha

(106 ac). Patch size was defined as $\geq$ 0.62 ha (1.5 ac) and < 43 ha. Dispersal distance was defined as 768 m (2,520 ft), twice the recorded distance.

Results & Discussion: The most suitable habitat for this species in the planning area is within the linkage and the desert mountain ranges, with very little highly suitable habitat identified in the San Bernardino Mountains (Figure 22). Movement of individuals between targeted protected areas is not the goal of linkage planning here; rather it is ensuring persistence of Merriam's kangaroo rat within the linkage so that multigenerational movement is possible. Both branches of the Least Cost Union provide contiguous highly suitable habitat for this species, though the western branch provides a more direct connection to highly suitable habitat on Grapevine Canyon Recreation Lands in the San Bernardino Mountains (Figure 22). The majority of suitable habitat was identified as potential core areas for this species (Figure 23). Distances among all core areas and patches are within the defined dispersal distance of this species (figure not shown), although barriers to movement may exist between suitable habitat patches. We conclude that the linkage is likely to serve the habitat and movement needs of Merriam's kangaroo rat.

Many small mammals, such as kangaroo rats, are reluctant to cross roads (Merriam et al. 1989, Diffendorfer et al. 1995, Brehme 2003) or are highly susceptible to road kill if they do cross. To restore and protect connectivity for Merriam's kangaroo rat, we recommend that:

- Crossing structures for small mammals are placed fairly frequently to facilitate movement across major transportation routes (Jackson and Griffin 2000, McDonald and St. Clair 2004), and existing road density is maintained in the linkage.

- Short retaining walls are installed in conjunction with crossing structures along paved roads in the Linkage Design to deter small mammals, amphibians, and reptiles from accessing roadways (Jackson and Griffin 2000).

- Lighting is directed away from the linkage and crossing structures.

Figure 22.
Habitat Suitability for Merriam's kangaroo rat
(Dipodomys merriami)

Degree of Suitability
- High
- Medium to High
- Medium
- Low to Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

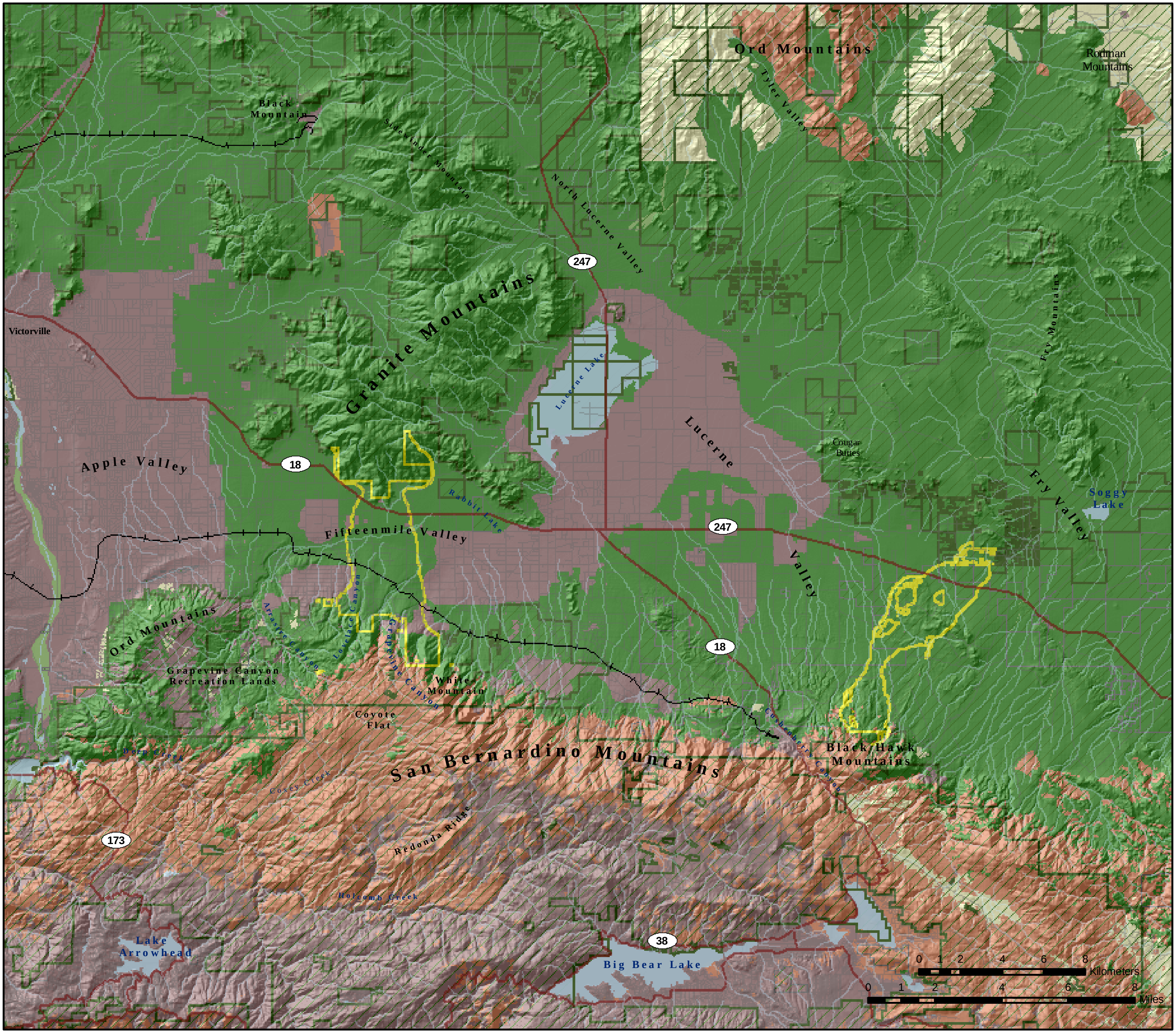

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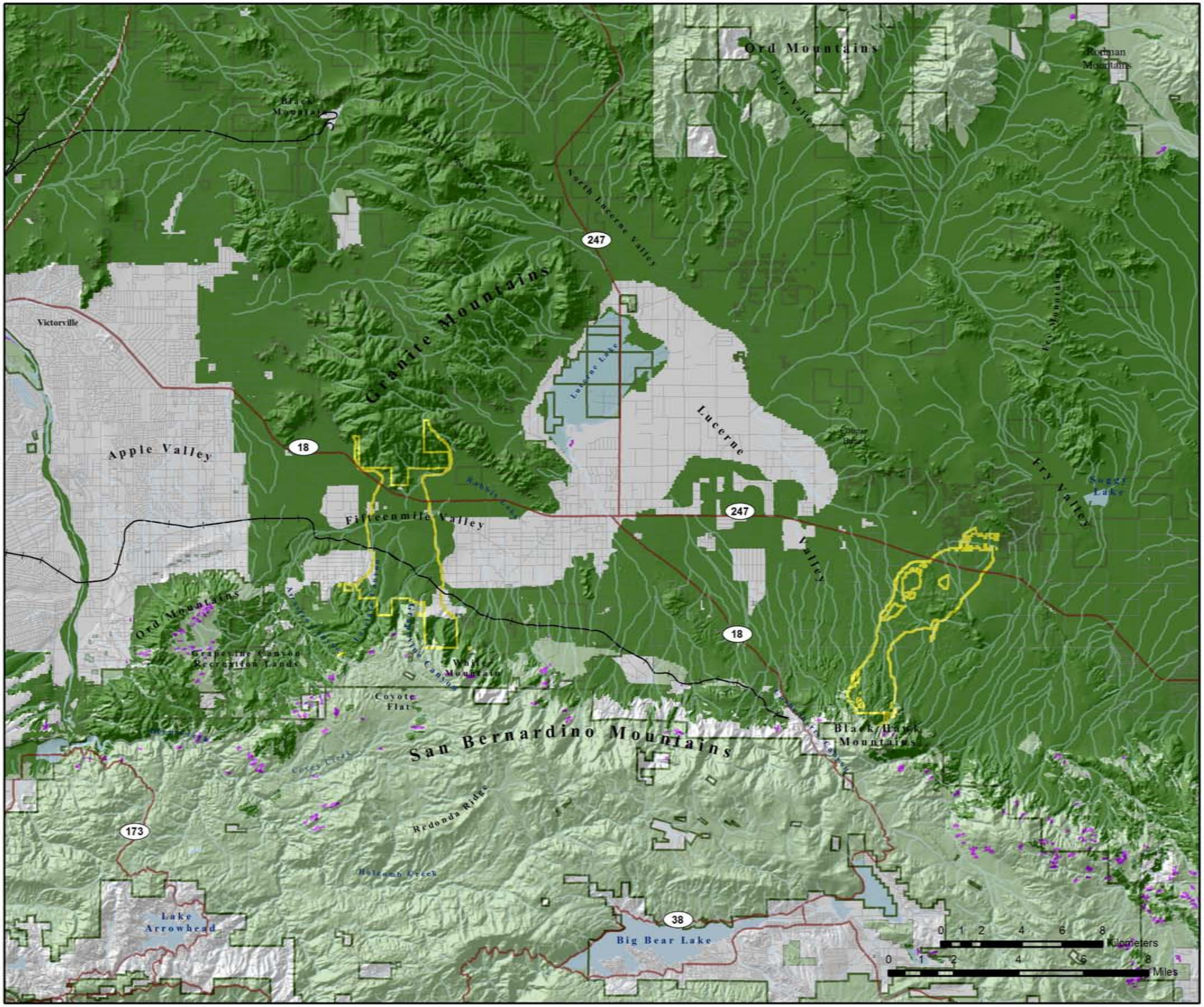
Figure 23.
Potential Cores & Patches for Merriam's kangaroo rat
(Dipodomys merriami)

- Core
- Patch
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads



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Pacific kangaroo rat (*Dipodomys agilis*)

Distribution & Status: The Pacific kangaroo rat was recently split into 2 species, *D. agilis* and *D. simulans* (Dulzura kangaroo rat); *D. agilis* occurs in the planning area. The distribution of these species extends from the coastal mountains of Baja California and southern California to the Santa Barbara-San Luis Obispo county line and inland to the Tehachapi and Piute Mountains, as far north as the South Fork of the Kern River (Best 1983, Zeiner et al. 1990, Sullivan and Best 1997). They occur at elevations up to about 2,133 m (7,000 feet) in scrub and chaparral habitats (W. Spencer pers. comm.) but have been found as high as 2,250 m (7,400 ft) (Zeiner et al. 1990). The Pacific kangaroo rat isn't afforded any special status.

Habitat Association: The Pacific kangaroo rat is a habitat generalist, occurring in a variety of open habitats with scattered vegetation including chaparral, oak woodland, pinyon-juniper woodland, desert scrub, and annual grassland (Bleich and Price 1995, W. Spencer pers. comm.). They have also been recorded in montane coniferous forests (Sullivan and Best 1997). They require friable soils in which to burrow (Zeiner et al. 1990). Goldingay and Price (1997) found them to be particularly abundant in ecotonal habitats. They increase in abundance following fires that create openings in dense vegetation (Price and Waser 1984, Price et al. 1991, W. Spencer pers. comm.). Quinn (1990) believes *D. agilis* to be most abundant in early succession communities that occur 2 to 5 years after fire, but smaller numbers of individuals can be found scattered in more limited openings in chaparral.

Spatial Patterns: MacMillen (1964) estimated home range size of Pacific kangaroo rat from 0.1 to 0.6 ha (0.4 to 1.5 ac) with a mean of 0.3 ha (0.8 ac). Although fairly widespread and common, they seem to occur at somewhat lower densities than other kangaroo rats, perhaps due to the more patchy nature of their habitat (sparse or open areas within scrub and chaparral, versus more homogeneous desert or grassland habitats), which may be the result of chaparral and scrub habitats providing less food (seeds from annual forbs and grasses) than grasslands and deserts (W. Spencer pers. comm.). Christopher (1973) measured population densities of the Pacific kangaroo rat that ranged from 0.9 to 10.8 per ha (2.2-26.7 ac).

Kangaroo rat tends to be more mobile than most rodents of their size. Little specific information is available on movements of Pacific kangaroo rat, but they are probably similar to Merriam's kangaroo rat, which is better studied. Zeng and Brown (1987) recorded long-distance movements up to 384 m (1,260 ft) in adult Merriam's kangaroo rats, concluding that they are opportunistic in moving into newly available habitat. However, unlike Merriam's kangaroo rat, the Pacific kangaroo rat may disperse between adjacent mountain ranges via linkages, at least over multiple generations (W. Spencer pers. comm.).

Conceptual Basis for Model Development: Movement between protected core areas in the linkage is multigenerational. This species prefers open vegetative communities including chaparral, desert scrub, annual grassland, oak woodland, pinyon-juniper woodland, and montane coniferous forests. They are primarily found between 800 and 2,250 m (2,625 to 7,382 ft) elevation (Sullivan and Best 1997). Core areas were defined as $\geq$ 8 ha (20 ac). Patch size was defined as $\geq$ 0.5 ha (1.2 ac) and < 8 ha. Dispersal distance for this species hasn't been measured, so we used twice the dispersal distance for Merriam's kangaroo rat (768 m; 2,520 ft).

Results & Discussion: Extensive suitable habitat was identified for the Pacific kangaroo rat throughout the planning area, with the most highly suitable habitat occurring in the San Bernardino Mountains (Figure 24). All branches of the Least Cost Union contain suitable habitat for this species with the most contiguous core habitat identified in the eastern branch (Figure 25). The majority of cores and patches of suitable habitat are within the dispersal distance defined for this species (figure not shown), although numerous barriers to movement may exist between suitable habitat patches. We conclude that the linkage is likely to meet the needs of this species.

Many small mammals are reluctant to cross roads (Merriam et al. 1989, Diffendorfer et al. 1995). To restore and protect connectivity for the Pacific kangaroo rat, we recommend that:

- Crossing structures for small mammals are placed fairly frequently to facilitate movement across major transportation routes.
- Short retaining walls are installed in conjunction with crossing structures along paved roads in the Linkage Design to deter small mammals, amphibians, and reptiles from accessing roadways (Jackson and Griffin 2000).

Figure 24
Habitat Suitability
for
Pacific kangaroo rat
(Dipodomys agilis)

Degree of suitability

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

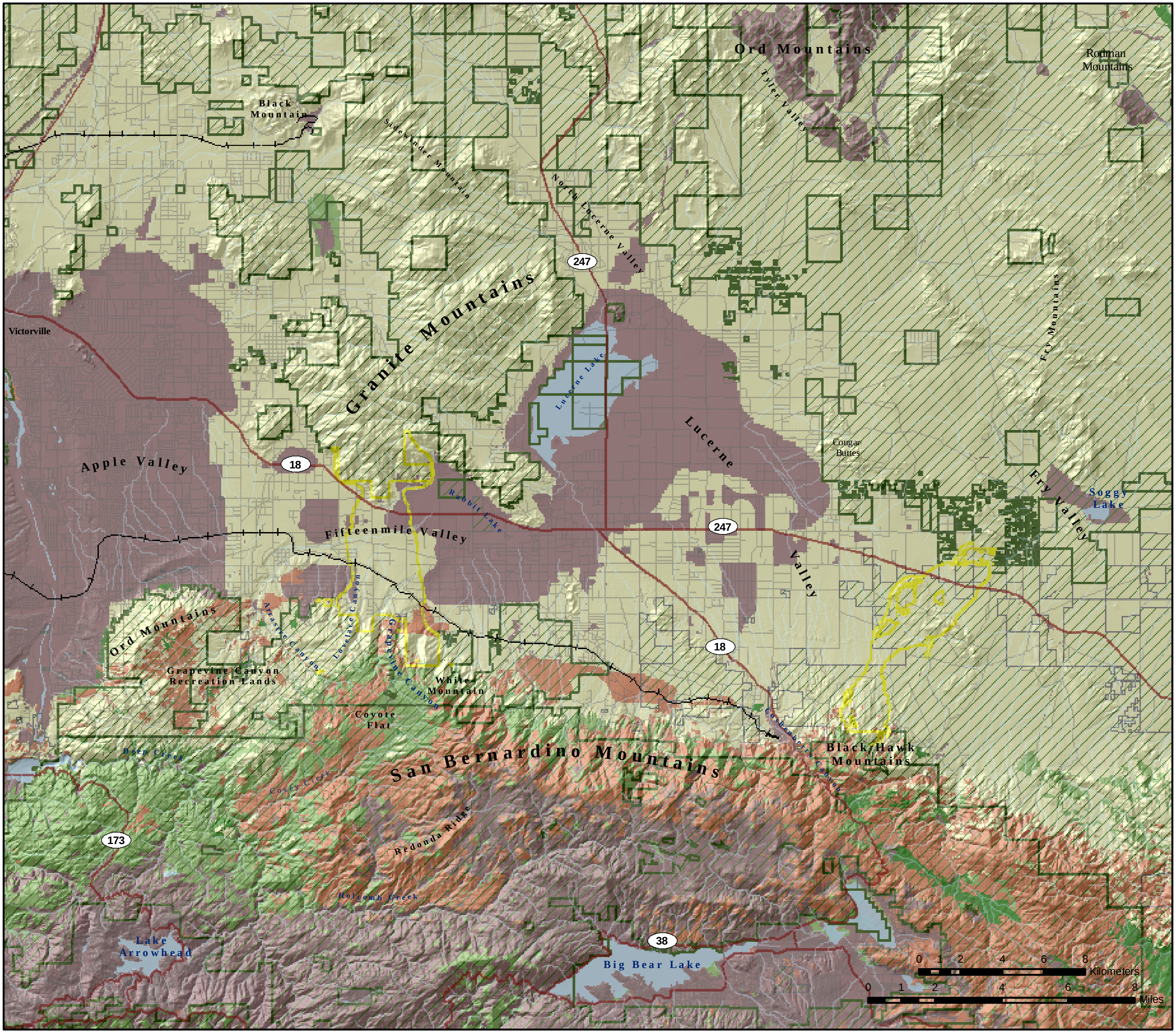

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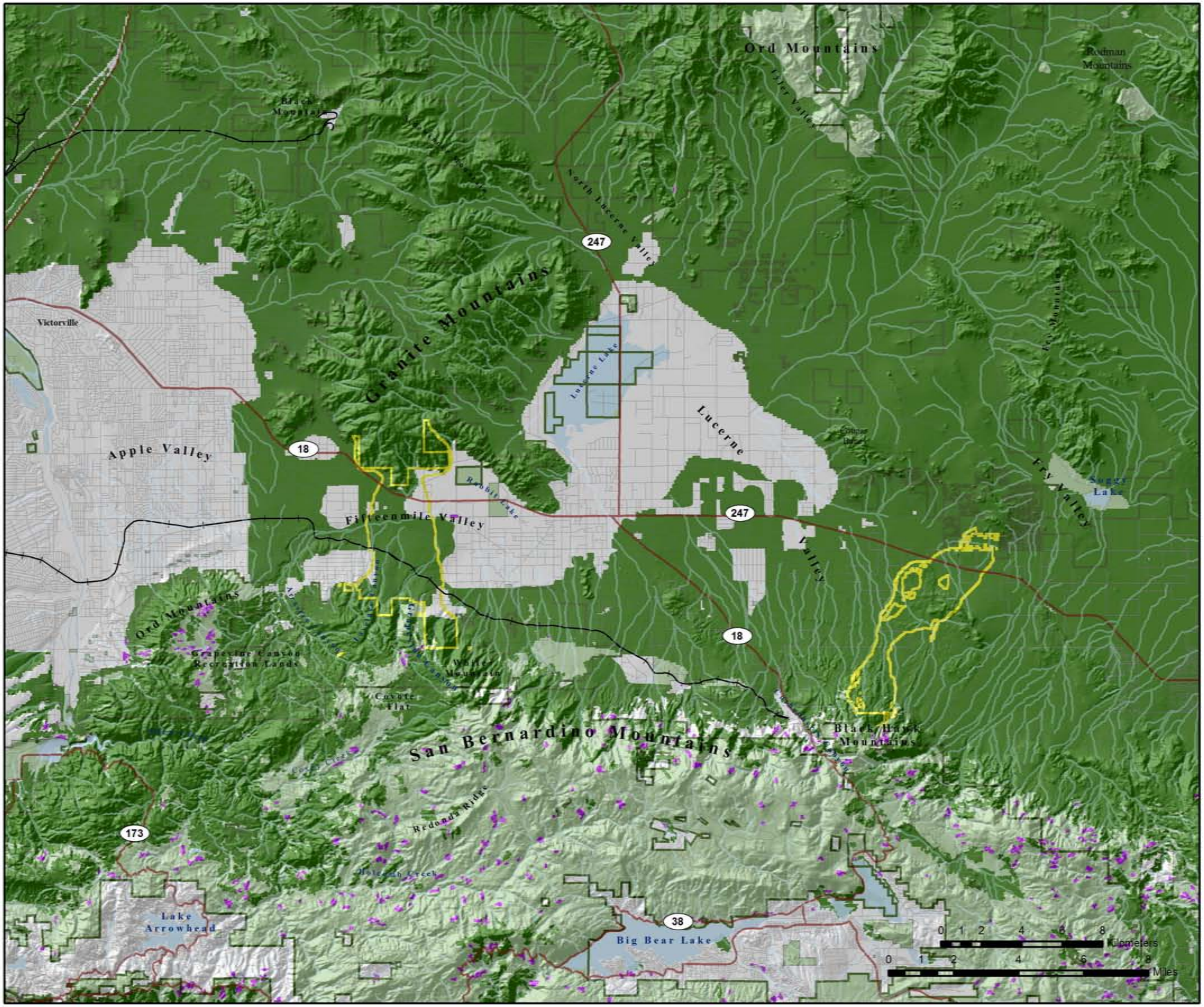
Figure 25.
Potential Cores & Patches for Pacific kangaroo rat
(Dipodomys agilis)



Core
Patch
< Patch
Least Cost Union
Target Areas
Protected Lands
Hydrography
Roads
Railroads

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Rock wren (*Salpinctes obsoletus*)

Justification for Selection: The rock wren is considered a habitat specialist because of its reliance upon habitat features that are very patchily distributed in the landscape.

Distribution & Status: Rock wrens have a vast geographic distribution, ranging from British Columbia to Central America and from the Pacific Coast eastward to the Great Plains (American Ornithologist Union 1998, Oppenheimer and Morton 2000). In southern California, they occur from northern San Luis Obispo County south to San Diego County (Small 1994). Rock wrens have one of the broadest altitudinal ranges of any North American bird (Small 1994); nests have been discovered at 75 m (246 ft) below sea level in Death Valley and as high as 4,267 m (14,000 ft) in the Sierra Nevada and White Mountains (Grinnell and Miller 1944, Small 1994, Oppenheimer and Morton 2000). The rock wren has no special status.

Habitat Associations: Although their range encompasses a huge area, they occupy a very specialized niche (Small 1994, Oppenheimer and Morton 2000). Rock wrens may be found in a variety of open habitats, including Great Basin scrub, desert scrub, chaparral, deep-cut arroyos, dry gravelly washes, and perennial grassland (Grinnell and Miller 1944, Bent 1948, DeSante and Ainley 1980, Zeiner et al. 1990, Small 1994), as well as pinyon-juniper woodland and the Bristlecone-Limber Pine Zone (Morrison et al. 1993). Within these habitats, they are restricted to rocky outcrops, talus slopes, cliffs, and earthen banks, which provide refuge, foraging and breeding sites (Grinnell and Miller 1944, Bent 1948, DeSante and Ainley 1980, Zeiner et al. 1990, Oppenheimer and Morton 2000). They may also utilize small mammal burrows (Small 1994).

Spatial Patterns: No information on home range or territory size was available in the literature, though several density estimates exist (Zeiner et al. 1990). In eastern Oregon, Anderson et al. (1972) found 25 breeding males per 40 ha (100 ac) in juniper-sage habitat. In Montana, Walcheck (1970) recorded 5 pairs per 40 ha (100 ac) in pine-juniper woodland. In Arizona, Hensley (1954) observed 5-8 pairs of rock wrens per 40 ha (100 ac) in the Sonoran Desert.

Research on the movement ecology of this species is lacking. Populations at higher elevations may move downslope in winter, while populations further north may migrate southward (Grinnell and Miller 1944, DeSante and Ainley 1980, Zeiner et al. 1990).

Conceptual Basis for Model Development: Rock wren movement in the linkage is likely multigenerational. They may utilize a variety of open habitats, including Great Basin scrub, desert scrub, pinyon-juniper woodland, deep-cut arroyos, dry gravelly washes, perennial grassland, as well as rocky outcrops and barren areas within chaparral, montane hardwood conifer and mixed coniferous forests. Core areas were defined as ≥ 290 ha (716 ac). Patch size was classified as ≥ 3.2 ha (7.9 ac) but less than 290 ha. Dispersal distance was not estimated for this species.

Results & Discussion: The habitat suitability analysis identified vast amounts of suitable habitat for rock wren, though the rocky outcrops preferred by this species are patchily distributed in these vegetation communities (Figure 26). Both branches of the Least Cost Union contain highly suitable core habitat for this species, with the western branch providing the most direct connection to large potential cores areas in the San Bernardino Mountains (Figure 27). We believe that the Least Cost Union is likely to serve the needs of this species.

To protect and maintain habitat for rock wren, we recommend that rock collecting in upland habitat and creeks and washes be discouraged, due to the resulting changes in habitat structure and possible disruption of nests.

Figure 26.
Habitat Suitability
for
Rock wren
(Salpinctes obsoletus)

Degree of Suitability
- High
- Medium to High
- Medium
- Low to Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

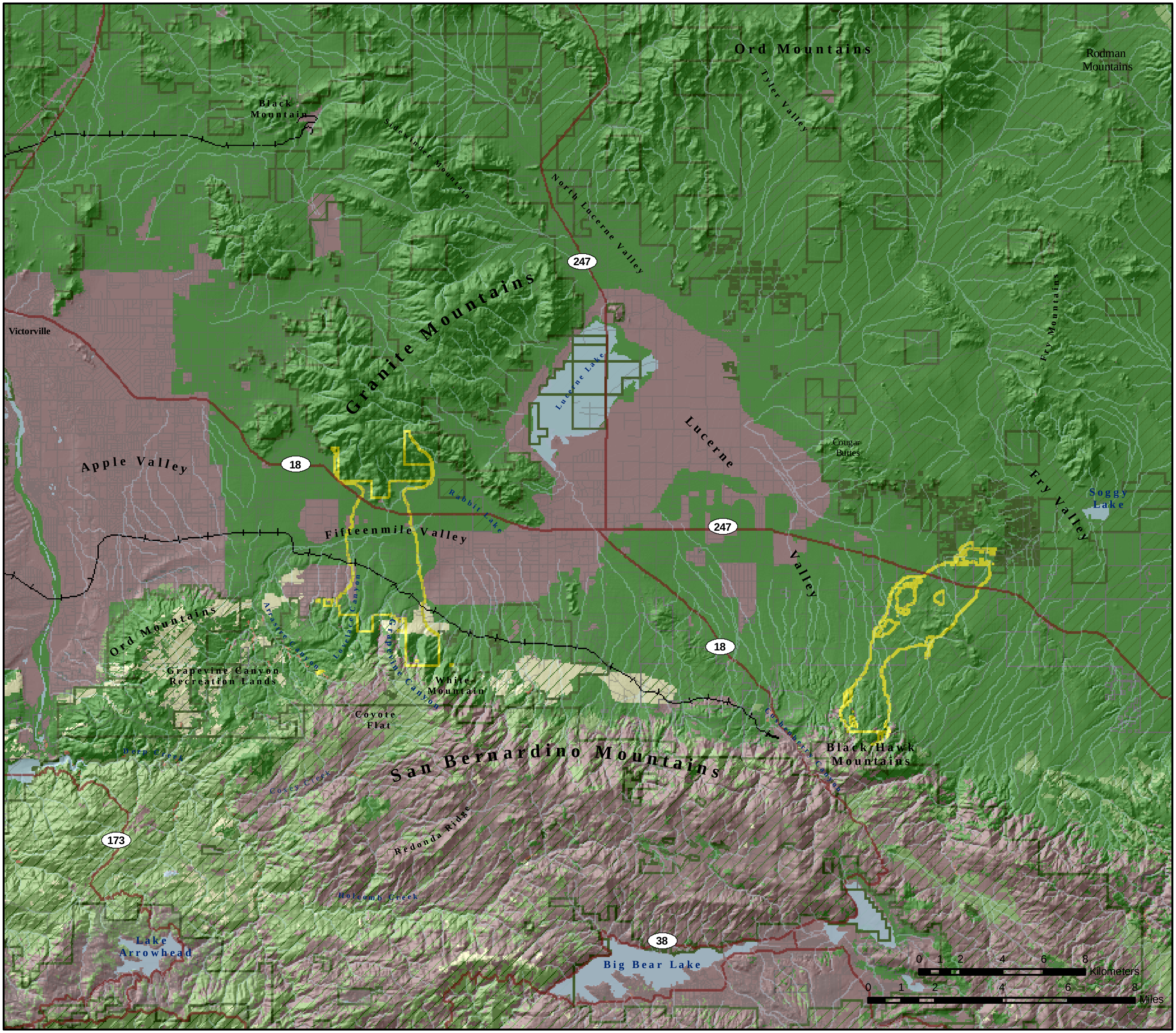

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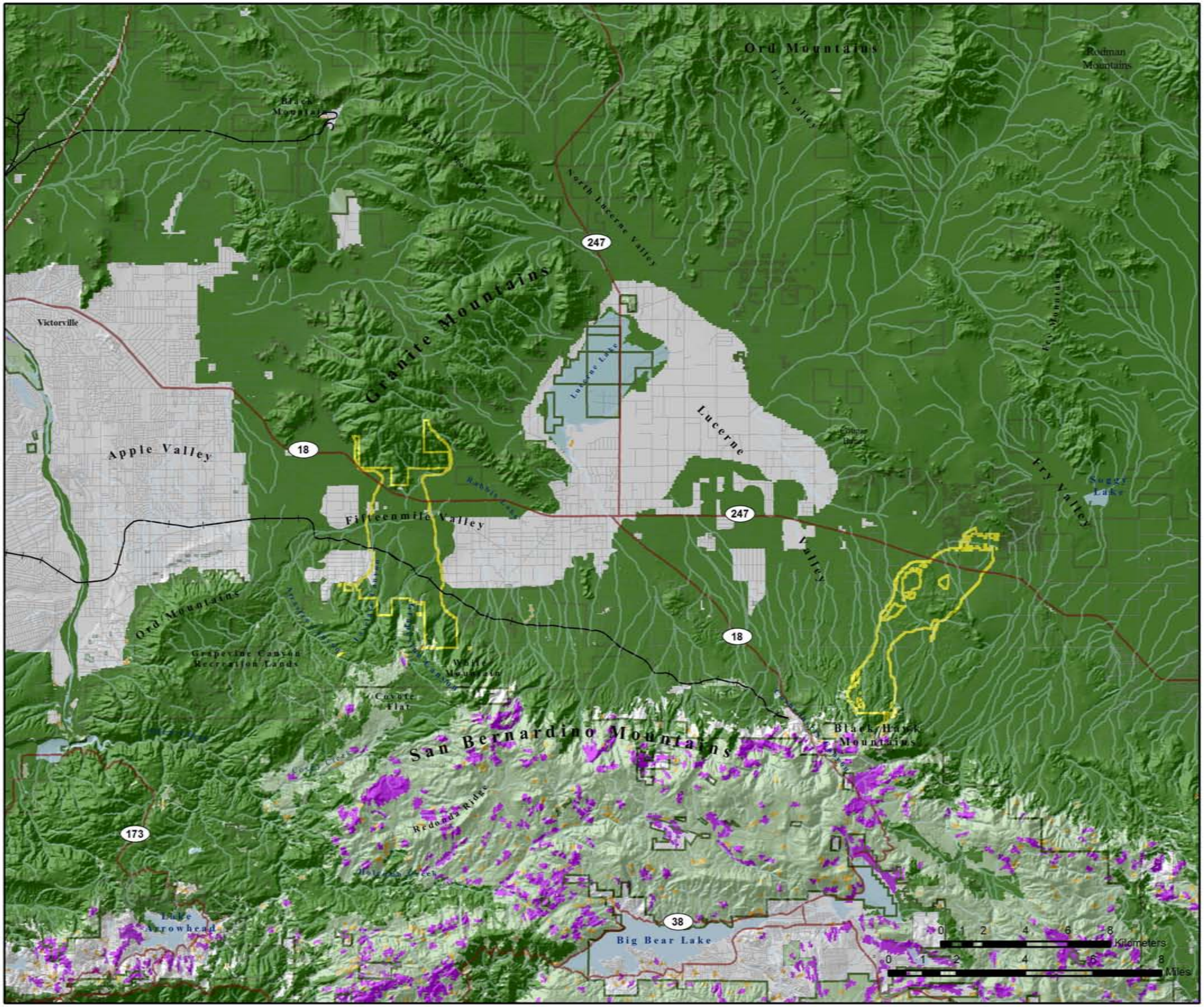
Figure 27.
Potential Cores & Patches for Rock wren
(Salpinctes obsoletus)



- Core
- Patch
- < Patch
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

N

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Cactus wren (*Campylorhynchus brunneicapillus*)

Justification for Selection: Habitat loss and fragmentation are a concern for this species. Historically, the interior and coastal populations were connected through the San Gorgonio Pass in Riverside County, but the connection has been severed due to urbanization of the pass (Rea and Weaver 1990, Solek and Sziji 2004).

Distribution & Status: The cactus wren is widely distributed from southern California south to southern Baja, and in parts of Nevada, Utah, Arizona, New Mexico, and Texas south to Mexico (Termes 1980, Dudek and Associates 2001). In California, the interior race is resident in the Mohave and Colorado deserts, from Mexico north to Inyo and Kern counties, while the coastal race is restricted to westward-draining slopes from Ventura County to San Diego County (Zeiner et al. 1990, Solek and Sziji 2004). Taxonomic affiliation of the coastal and interior populations is still being debated (Rea and Weaver 1990, Solek and Sziji 2004).

The coastal race is considered a California Species of Special Concern due to habitat loss, degradation, and fragmentation (Solek and Sziji 2004). Activities that are known to adversely impact the species include weed abatement projects, legal and illegal grading or clearing activities, and some recreational activities (Harper and Salata 1991, Solek and Sziji 2004). Overly frequent fire eliminates the dense, older cactus patches required as habitat. The domestic cat is the most dangerous predator (Anderson and Anderson 1963, Solek and Sziji 2004).

Habitat Associations: Cactus wrens may be encountered in desert scrub, desert succulent scrub, Joshua tree, and desert wash habitats (Zeiner et al. 1990). They depend on thickets of xeric vegetation for cover and thermal relief. Nests are found in branching cacti, thorny scrub, and small trees (e.g., Joshua tree), with nests also used as roosts (Grinnell and Miller 1944, Anderson and Anderson 1957, Zeiner et al. 1990).

Spatial Patterns: The home range of cactus wrens may be maintained throughout the year (Anderson and Anderson 1963, Zeiner et al. 1990). In Arizona, Anderson and Anderson (1973) found an average home range size of 1.9 ha (4.8 ac), varying from 1.2-2.8 ha (2.9-6.9 ac; Zeiner et al. 1990). In San Diego County, California, Rea and Weaver (1990) found smaller home ranges from 0.8 to 2 ha, (2 to 4.9 ac) with an average of 1.3 ha (3.2 ac). On Camp Pendleton, home range size varied from 0.5-2 ha (1.2 to 4.9 ac) (Solek and Sziji 2004).

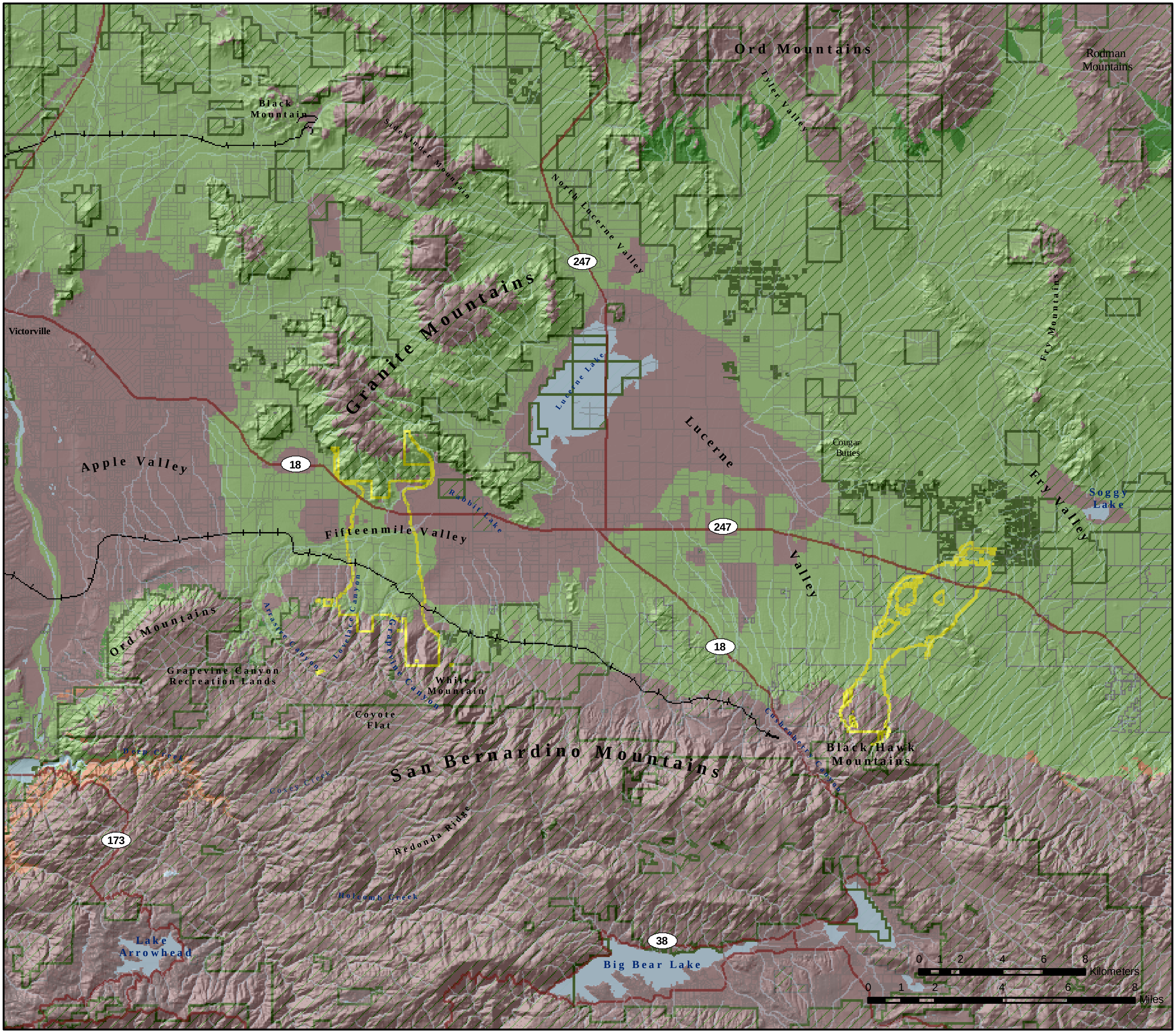
Atwood (1998) found an average dispersal distance of 1.59 km (0.98 mi) for juvenile cactus wrens on the Palos Verdes Peninsula, but this isolated coastal population has limited dispersal options. In Arizona, Anderson and Anderson (1973) found juvenile females dispersed farther away from their natal territories than juvenile males (Solek and Sziji 2004).

Conceptual Basis for Model Development: Cactus wrens prefer desert scrub, desert succulent scrub, Joshua tree, and desert wash habitats. Potential core areas were defined as greater than or equal to 33 ha (81.5 ac). Patch size was classified as $\geq$ 2 ha (4.9 ac) but less than 33 ha. Dispersal distance was defined as 3.18 km (1.96 mi).

Results & Discussion: The model results identified extensive highly suitable habitat for cactus wren in the desert mountain ranges and in the linkage planning area, but very little potential habitat in the San Bernardino Mountains within the analysis window (Figure 28). Ensuring persistence of cactus wren within the linkage is the planning goal here and both branches of the Least Cost Union contain contiguous highly suitable core habitat for this species (Figure 29). Distances among all cores and patches of suitable habitat are within the dispersal distance of this species (figure not shown), but barriers may exist between suitable habitat patches. We conclude that the linkage will likely serve the needs of cactus wren.

To protect and restore habitat connectivity for cactus wren, we recommend that fire frequency be controlled to prevent type conversion of desert scrub habitats to nonnative annual grassland (Winter 2003).

Figure 28.
Habitat Suitability
for
Cactus wren
(Campylorhynchus brunneicapillus)



Degree of Suitability
- High
- Medium to High
- Medium
- Low to Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

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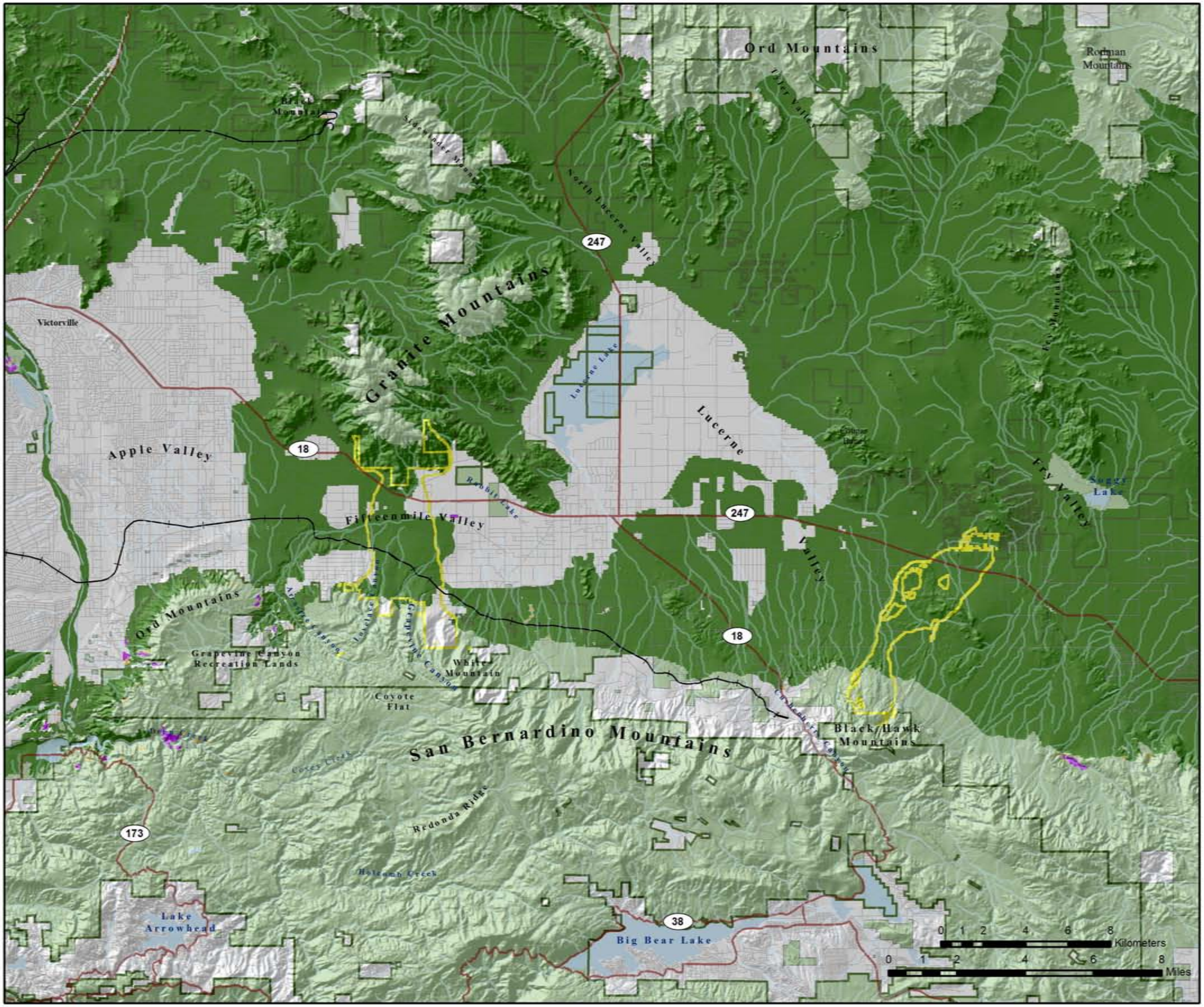
Figure 29.
Potential Cores & Patches for Cactus wren
(Campylorhynchus brunneicapillus)

- Core
- Patch
- < Patch
- Least Cost Union
- Protected Lands
- Target Areas
- Hydrography
- Roads
- Railroads



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Speckled rattlesnake (*Crotalus mitchellii*)

Justification for Selection: This reptile depends on a variety of desert and chaparral habitats. Rattlesnakes are often destroyed when encountered by humans, and are also killed while crossing roads.

Distribution & Status: The distribution of the speckled rattlesnake largely coincides with the Mohave and Sonoran Deserts, but the species may also be encountered on the southern fringes of the Great Basin Desert and in the mountains and coastal facing canyons of San Diego, Riverside, and Orange counties. It occurs from 300-2,200 m (1,000-7,300 ft) elevation (Klauber 1936, Stebbins 1954, Klauber 1972, Zeiner et al. 1988, Melli 2000).

The speckled rattlesnake is not listed as sensitive by any government entities, though more snakes are vulnerable to extinction than is currently recognized (Melli 2000).

Habitat Associations: The speckled rattlesnake inhabits a wide range of desert and chaparral habitats but may also utilize pinyon-juniper, valley foothill woodland, and conifer habitats (Klauber 1936, Stebbins 1954, Klauber 1972, Zeiner et al. 1988), as well as alluvial deposits in the desert (Melli 2000). They strongly prefer rocky habitats and may be found on steep hillsides, in deep canyons, or in other areas with adequate rocky substrate and dense vegetation. Rock formations, vegetation and mammal burrows provide shelter (Klauber 1936, Stebbins 1954, Klauber 1972, Zeiner et al. 1988).

Spatial Patterns: No data are available on home range or dispersal for the speckled rattlesnake (Zeiner et al. 1988). However, high-elevation populations of this species are known to move considerable distances to winter hibernacula (Klauber 1972, Zeiner et al. 1988). A closely related species, the red diamond rattlesnake (*C. ruber ruber*) has been more thoroughly researched. In the red diamond rattlesnake, home range sizes of males are larger than those of females and range between 0.5 and 5 ha (1.2-12.4 ac; Tracey 2000). Home ranges of males and females can overlap (T. Brown pers. comm.).

The only reported movement distances for the red diamond rattlesnake are for adults on their home ranges: males can move 400-700 m (1,312-2,297 ft) from den sites (Tracey 2000). Fitch and Shirer (1971) measured average daily movements for adults at 45 m (147 ft) and found that 10% percent of moves were greater than 150 m (492 ft). Juveniles are more likely to disperse long distances, but no movement data are available for this life stage (Tracey 2000).

Conceptual Basis for Model Development: Suitable habitats for speckled rattlesnakes are chaparral, desert scrub, desert wash, pinyon-juniper, Joshua tree, valley foothill woodland, and conifer habitats types between 300-2,200 m elevation. Core areas were defined as greater than or equal to 2.5 km^2 (617 ac). Patch size was classified as $\geq$ 0.10 km^2 (24.7 ac) but < 2.5 km^2. Dispersal distance is 1400 m (4,593 ft), or twice the maximum recorded movement for an adult red-diamond rattlesnake.

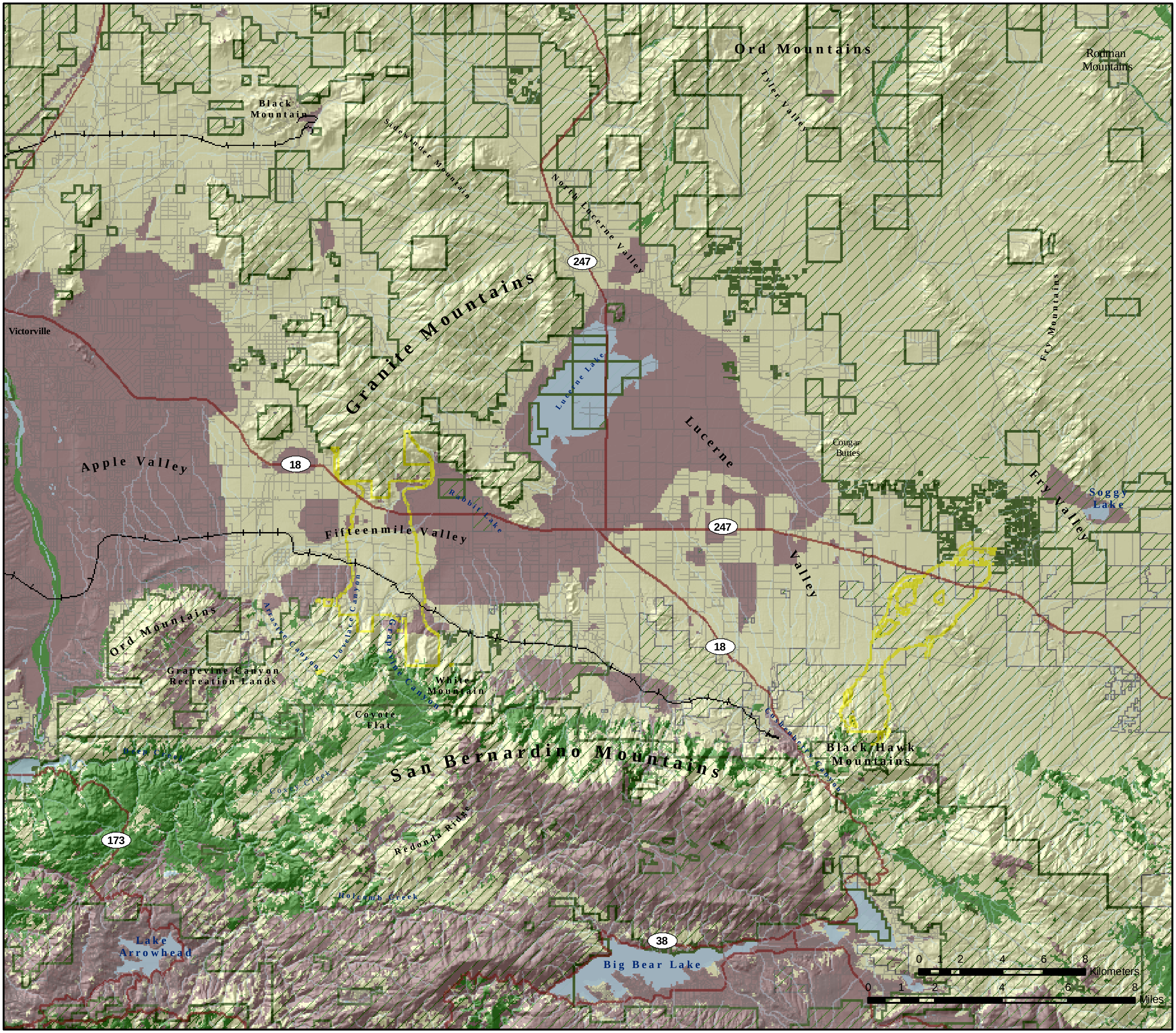
Results & Discussion: Suitable habitat for the speckled rattlesnake is widespread in the planning are, with chaparral habitats in the San Bernardino Mountains providing the most highly suitable habitat (Figure 30). Almost all suitable habitat identified in the planning area was designated as potential core areas for this species with fairly contiguous core habitat identified in both branches of the Least Cost Union (Figure 31). Rattlesnakes are able to move among habitat patches due to the relatively high levels of habitat continuity (figure not shown), though barriers to movement may exist between suitable habitat patches. We conclude the linkage is likely to serve this species.

To protect and restore habitat connectivity for the speckled rattlesnake, we recommend that:

- Crossing structures be placed fairly frequently to facilitate movement across major transportation routes (Jackson and Griffin 2000, McDonald and St. Clair 2004).

- Fire frequency is controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland.

Figure 30.
Habitat Suitability for Speckled rattlesnake
(Crotalus mitchellii)



Degree of Suitability
- High
- Medium
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

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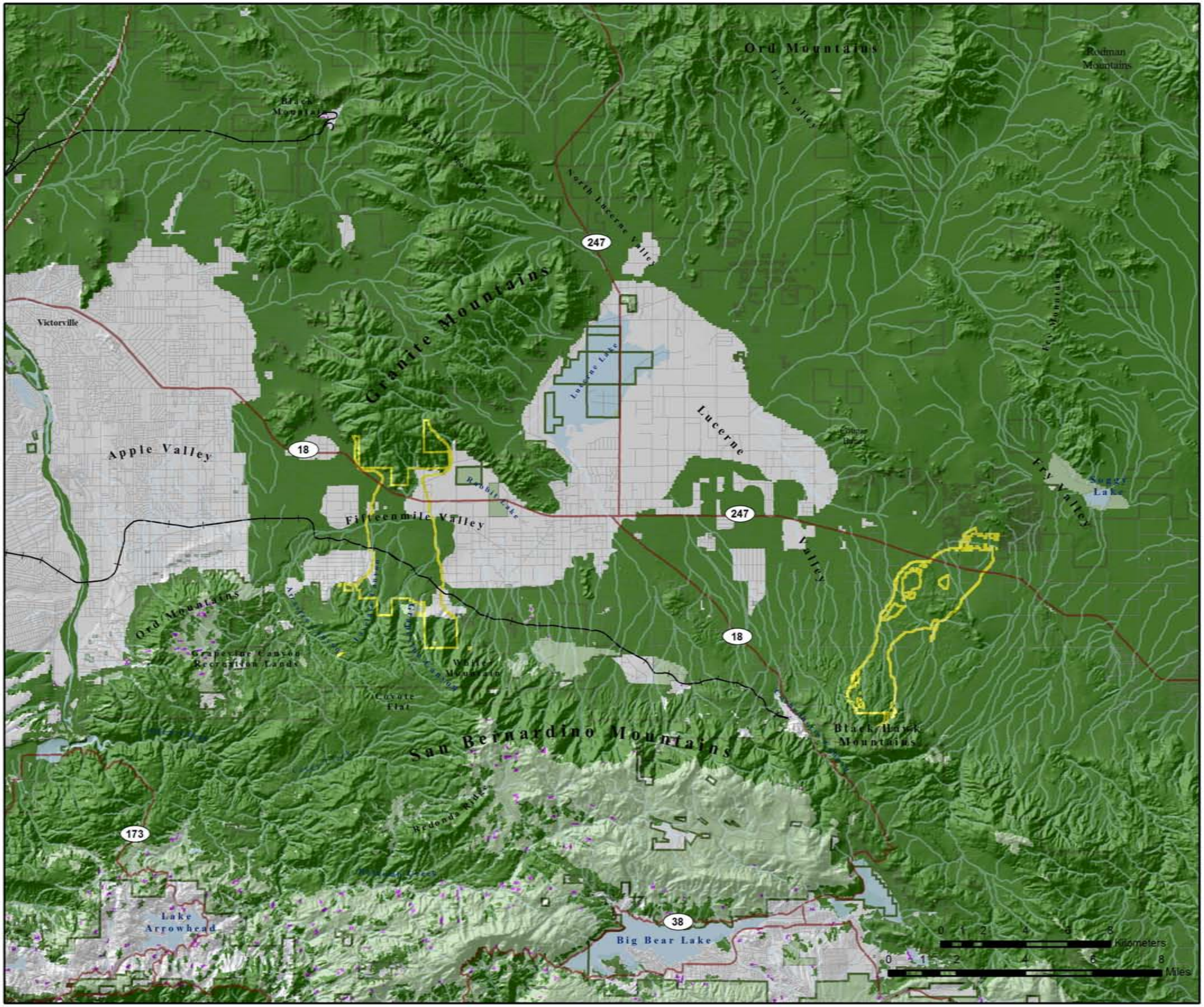
Figure 31.
Potential Cores & Patches for Speckled rattlesnake
(Crotalus mitchellii)

Core
Patch
Least Cost Union
Target Areas
Protected Lands
Hydrography
Roads
Railroads



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Tarantula hawk (*Pepsis* spp.)

Justification for Selection: Tarantula hawks are sensitive to changes in habitat and highways may be impediments to their movement (Pratt and Ballmer, pers. comm.).

Distribution & Status: *Pepsis* is a New World genus with 15 species in the United States. *Pepsis formosa* and *P. thisbe* are the most common species in the southwest (Williams undated material). Tarantula hawk distributions are strongly related to the availability of their primary prey, tarantulas (*Aphonopelma* spp.; Hogue 1974, Williams undated material, Pratt and Ballmer, pers. comm.). They may be found at elevations up to 2,286 m (7,500 ft), but are typically encountered at lower elevations (Pratt and Ballmer, pers. comm.)

Habitat Associations: Tarantula hawks are associated with communities where milkweed and other nectar sources are available for adults, and host tarantulas are present (Vincent 2000, Pratt and Ballmer, pers. comm.). They may be encountered in coastal sage scrub, alluvial fan scrub, montane chaparral and high desert scrub habitats. Adults are vegetarian, using nectar from a variety of flowers, while the larvae are carnivores and feed on tarantulas (Vincent 2000). Male tarantula hawks engage in a behavior known as hilltopping, in which they stake out territories to find mates (Alcock and Bailey 1997, Williams undated material).

Spatial Patterns: Tarantula hawks have a fairly lengthy flight season (Alcock 1981, Alcock and Carey 1988, Alcock and Bailey 1997). Males are territorial, defending tall shrubs or small trees growing along ridges and hilltops (Alcock and Bailey 1997). Territorial defense is exhibited during the mating season. Typically there is only one resident per plant and sites are well spaced (Alcock 1981). Home range has been estimated at 3.8 km^2 (1.5 mi^2; Pratt and Ballmer, pers. comm.). No movement or dispersal estimates were available for tarantula hawks.

Conceptual Basis for Model Development: Tarantula hawks may be found in many habitats that offer nectar sources. The following vegetation communities were considered suitable: coastal sage scrub, sagebrush, mixed chaparral, montane chaparral, and chamise-redshank chaparral, below 2,286 m. Core areas were defined as 95 km^2 (23,475 ac). Patch size was classified as 7.6 km^2 (1,878 ac). Access to hilltopping habitat is critically important for population persistence, thus we identified all ridges within 2.41 km (1.5 mi) of appropriate vegetation communities to include them as potential habitat.

Results & Discussion: The model identified fairly extensive suitable habitat and hilltopping opportunities for tarantula hawks in the San Bernardino Mountains, with habitat more limited in the desert mountain ranges (Figure 32). Potential core areas were identified in the San Bernardino Mountains, with large patches of habitat identified near Tyler Valley in the Ord Mountains (Figure 33). Very little suitable habitat was identified for this species in the Least Cost Union. However, given that this terrestrial invertebrate uses nectar sources found in a variety of habitats (Vincent 2000), we conclude that the linkage may accommodate this species, at least during the blooming period.

To restore and protect habitat connectivity for this species, we recommend that:

- Nectar sources and habitat quality are maintained in the linkage.
- Fire frequency is controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland.
- Access to hilltopping habitat in the linkage and core areas is maintained.

Figure 32.
Potential Habitat
for
Tarantula hawk

(Pepsis spp.)

- Potential Habitat
- Hilltopping Habitat
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads

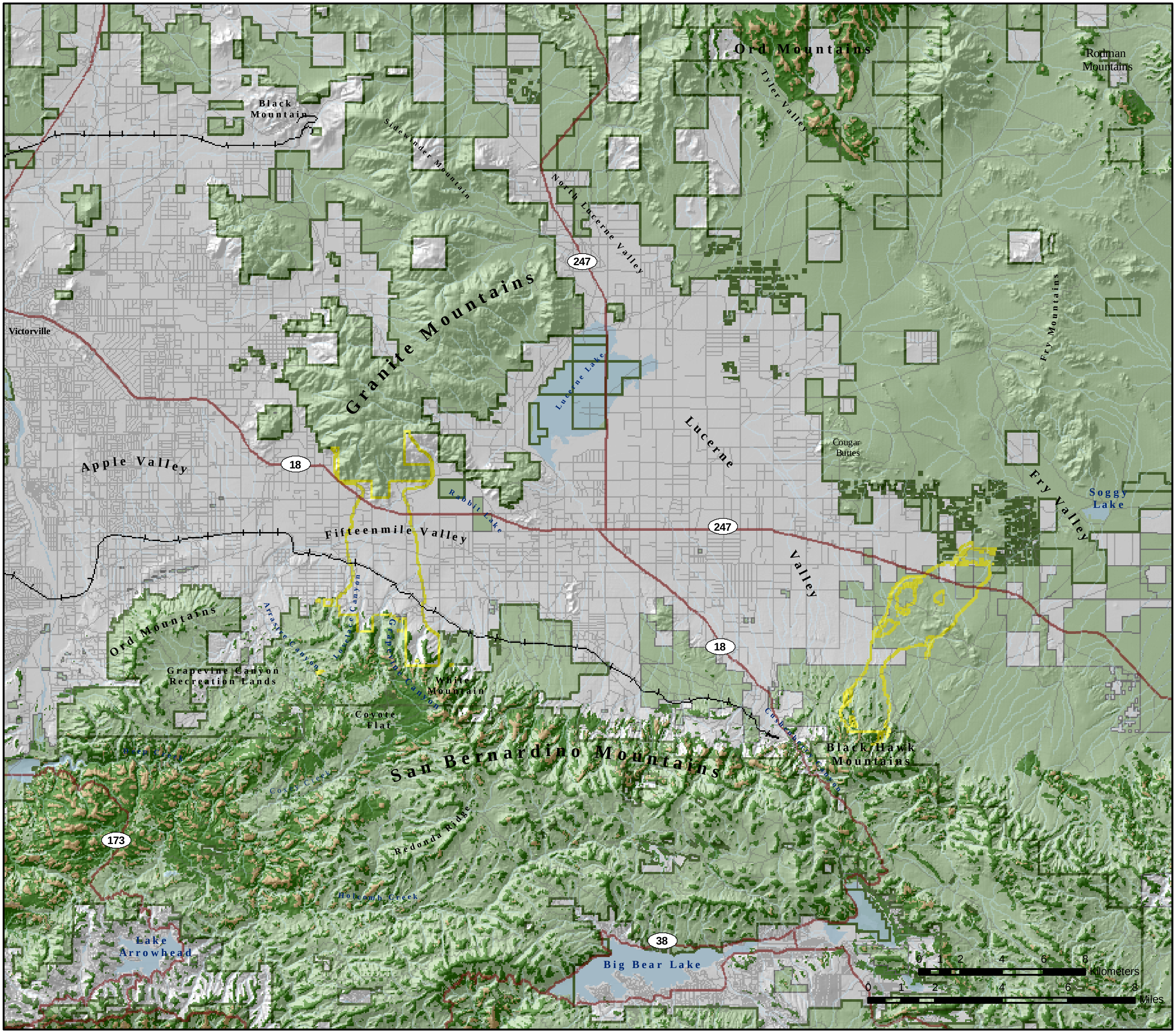

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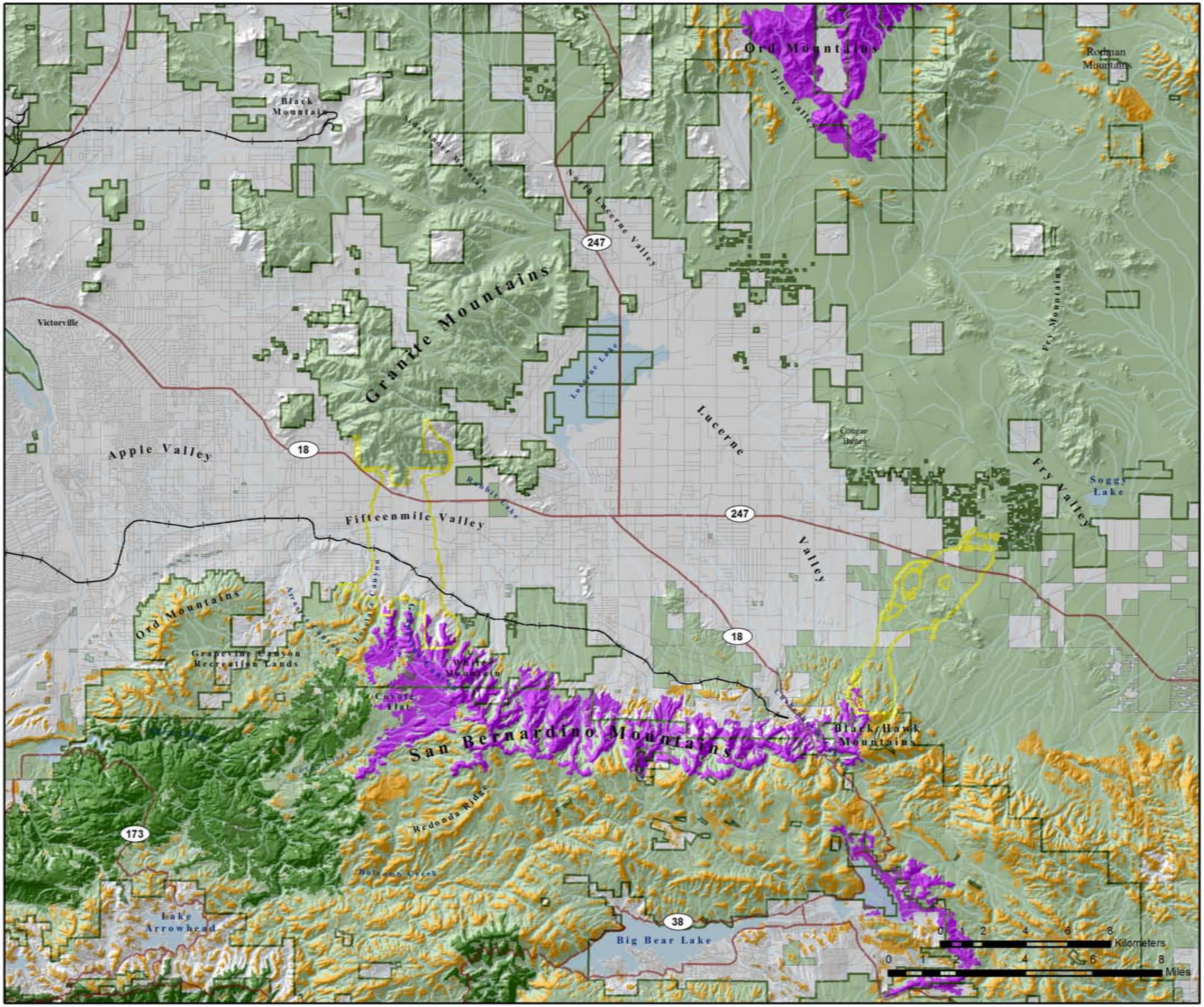
Figure 33.
Potential Cores & Patches
for
Tarantula hawk
(Pepsis spp.)



Core
Patch
< Patch
Least Cost Union
Target Areas
Protected Lands
Hydrography
Roads
Railroads

N

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Metalmark butterfly (*Apodemia mormo*)

Justification for Selection: The metalmark butterfly was selected due to limited dispersal capabilities and vulnerability to roadkill. Roads are significant barriers for this species (Pratt and Ballmer pers.com).

Distribution & Status: There are 9 species in the genus *Apodemia* (Powell 1975). Although the species *A. mormo* is distributed throughout the western United States and south into Baja California Mexico (Orsak 1977, Scott 1986, Struttman and Opler 2000), the subspecies *A. m. virgulti* occurs only in southern California and south into neighboring Mexico (Orsak 1977). The metalmark butterfly may occur from sea level up to 1,254 m (5,000 ft) elevation (Orsak 1977, Pratt and Ballmer pers.com).

Habitat Associations: This butterfly inhabits arid habitats, such as dry, rocky slopes in desert scrub or xeric chaparral-covered hills, but may also be found in grassland, open woodland, and dune habitats (Scott 1986, Prchal and Brock 1999, Struttman and Opler 2000), as well as coastal sage scrub (Pratt and Ballmer pers.com). Larval host plants include Wright's buckwheat (*Eriogonum wrightii*), Heerman's buckwheat (*E. heermannii;* Pratt and Ballmer 1991, Prchal and Brock 1999), and California buckwheat (*E. fasciculatum;* Orsak 1977). Young caterpillars feed on leaves, while older caterpillars consume both leaves and stems (Scott 1986, Struttman and Opler 2000). Each caterpillar undergoes five stages of growth (instars) prior to transforming into a butterfly (Ballmer and Pratt 1988). Adult nectar sources include many species of buckwheat, as well as other plants, such as Ragwort (*Senecio* sp.) and Rabbitbrush (*Chrysothamnus* sp.; Struttman and Opler undated mat.).

Spatial Patterns: The metalmark's flight season is from March to October (Scott 1986, Struttman and Opler 2000), with a peak in late March (Orsak 1977). They live for a little over a week, with an average lifespan of 9 days and 11 days for males and females, respectively (Scott 1986). During this time, they must feed and mate, and females have to locate a host buckwheat plant on which to deposit their eggs before they perish (Essig Museum, undated material). Most of their activities take place in the open; they prefer full sun (Scott 1986). Although density estimates are lacking, metalmarks can be quite abundant in inland areas, particularly in undisturbed foothill habitats (Orsak 1977). Home range has been estimated at 100 m^2 (1,076 ft^2; Pratt and Ballmer pers.com).

Typically, metalmarks make very limited movements during their life spans, averaging 49 m (161 ft) for males and 64 m (210 ft) for females. The longest recorded movement was 617 m (2,024 ft; Scott 1986).

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. The metalmark butterfly prefers dry, rocky slopes in desert scrub or chaparral, but may also be found in coastal sage scrub, grassland, open woodland, and dune habitats. Within these communities, they may be found from sea level up to 1254 m (5,000 ft) in elevation. Dispersal distance was defined as 1,234 m (4,048 ft).

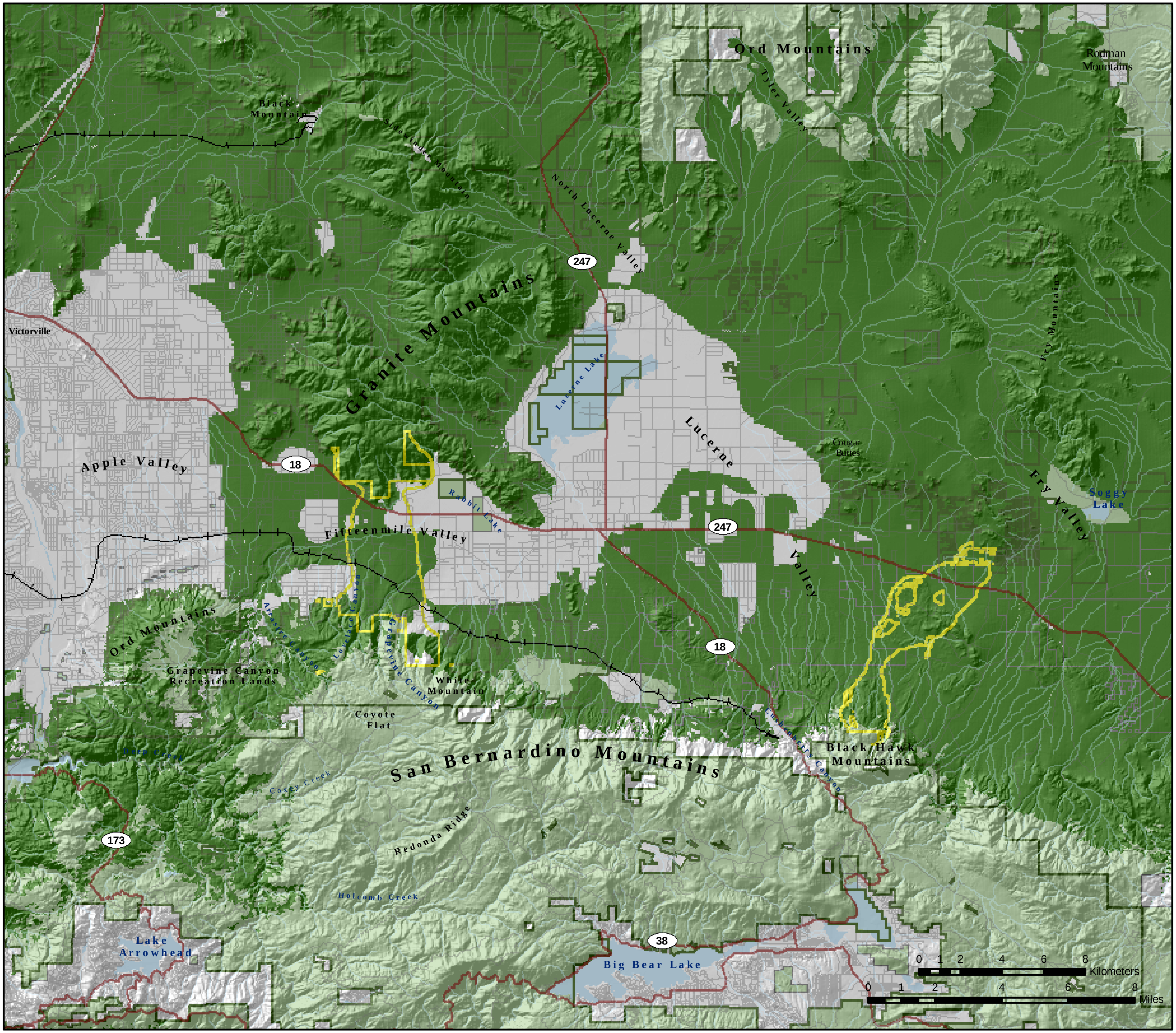
Results & Discussion: Suitable habitat for the metalmark butterfly is fairly widespread in the planning area (Figure 34), largely following the distribution of desert scrub and chaparral habitats. Potentially suitable habitat was captured in both branches of the Least Cost Union, with the western branch providing a more direct connection to suitable habitat in the San Bernardino Mountains. Almost all suitable habitat patches were within the dispersal distance of this species (figures not shown), although barriers to movement may exist between suitable habitat patches. We concluded that the linkage will likely serve the needs of this species.

To protect and restore habitat and connectivity for the metalmark butterfly, we recommend that:

- Host plants and nectar sources, such as rabbitbrush, ragwort, and various species of buckwheat are maintained in the linkage.

- Fire frequency is controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland.

Figure 34.
Potential Habitat for Metalmark butterfly
(Apodemia mormo)



Potential Habitat
Least Cost Union
Target Areas
Protected Lands
Hydrography
Roads
Railroads

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Green hairstreak butterfly (*Callophrys affinis perplexa*)

Justification for Selection: The green hairstreak butterfly was chosen as a habitat quality indicator. It is a good species for monitoring habitat health in the linkage (Pratt and Ballmer pers.com).

Distribution & Status: There are 4 recognized subspecies. *C. a. perplexa* occurs from lowland California to western Oregon, Carson Range of Nevada, and Puget Sound in Washington (Scott 1986). This butterfly is typically found below 1,254 m (5,000 ft) in elevation (Pratt and Ballmer pers.com).

Habitat Associations: The green hairstreak butterfly prefers open habitats such as coastal sage and desert scrub. It is considered an indicator species for coastal sage scrub (Pratt and Ballmer pers.com). It may also be found in woodland, chaparral, and sagebrush habitats if the canopy is sparse (Scott 1986). Larval host plants may include several buckwheat species (*Eriogonum* spp.), deerweed (*Lotus scoparius*) and other species of *Lotus*, as well as wild lilacs (*Ceanothus* spp.; Orsak 1977, Scott 1986, Heath 2004). Adults primarily use buckwheat plants as nectar sources (Heath 2004).

The larvae of this species have a symbiotic relationship with ants. Ants protect butterfly larvae and pupae from predators, even carrying them to ant nests for shelter, where they may pupate (Downey 1961, Orsak 1977). In return, the larvae exude a honey like fluid that is consumed by the tending ants (Downey 1961, Orsak 1977).

Spatial Patterns: The flight season for the green hairstreak butterfly is in spring, usually from late February to April, although populations at higher elevations may have a later season (Scott 1986, Pratt and Ballmer pers.com). Individuals may live up to 19 days in nature (Scott 1986). The hairstreak is territorial, with an average home range size of 100 m^2 (1,076 ft^2; Pratt and Ballmer pers.com).

This species is not considered a good disperser, but individuals will fly to high points where they engage in a behavior known as hilltopping to search for mates (Scott 1986, Pratt and Ballmer pers.com). They may travel along ridgetops and dry streams (Santa Barbara Museum of Natural History, undated mat.). Orsack (1977) typically encountered them along foothill ridges. Males may be found perching on overhanging branches along washes and openings in chaparral (Emmel and Emmel 1973).

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. This species is an indicator for coastal sage scrub but may also be encountered in desert scrub, sagebrush, and open woodland and chaparral habitats below 1,254 m in elevation. Access to hilltopping habitat is critically important for population persistence, thus we identified all ridges within 100 m (328 ft) of appropriate vegetation communities to include them in potential habitat.

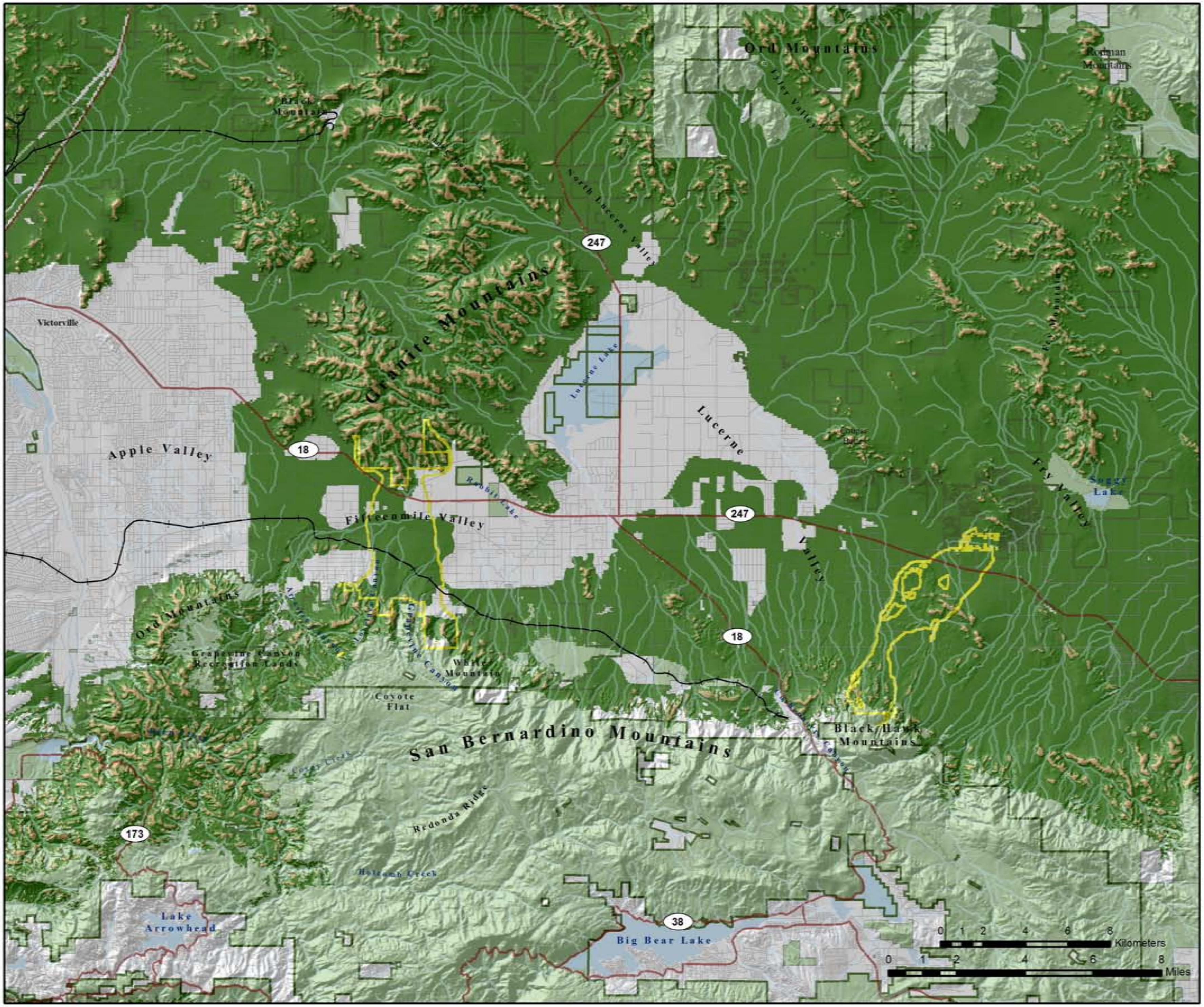
Results & Discussion: Potential habitat for the green hairstreak butterfly was identified in the chaparral habitats along the foothills of the San Bernardino Mountains and in the scrub communities of the desert, with hilltopping habitat most pronounced in the Granite Mountains (Figure 35). Both branches of the Least Cost Union provide suitable habitat for this species. We conclude that the linkage will likely serve the needs of the green hairstreak butterfly.

To protect habitat connectivity for the green hairstreak butterfly, we recommend that:

- Larval host plants and nectar sources (deerweed, ceanothus, and various species of buckwheat) are maintained in the linkage.
- Fire frequency is controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland.
- Access to hilltopping habitat is maintained in the linkage and core areas.
- Native ant populations are maintained in the linkage and core areas.

Figure 35.
Potential Habitat
for
Green hairstreak butterfly
(Callophrys perplexa)

- Potential Habitat
- Hilltopping Habitat
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads



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Joshua tree (*Yucca brevifolia*)

Justification for Selection: The transfer of pollen in this species, which represents the transfer of genes, is largely dependent on one species of moth pollinator, the yucca moth (*Tegeticula synthetica*; Keeley et al. 1984, Tirmenstein 1989, Gossard 1992). Habitat loss and encroachment may cause population deterioration of the yucca moth through pesticide use, which will also adversely affect Joshua tree populations (Gossard 1992). Numerous other species depend on the Joshua tree as a resource for food, or as a home, perch, nest site, or cover (Miller and Stebbins 1964, Bakker 1971, Gossard 1992).

Distribution and Status: The Joshua tree is endemic to the Mohave Desert, which encompasses parts of California, Nevada Utah, and Arizona (Hickman 1993). In California, Joshua trees are found between 500-2,000 m (1,640-6,562 ft) elevation (Vogl 1976, Munz 1974, Rowlands et al. 1982, Gossard 1992, Hickman 1993). Paleontological research has shown that Joshua trees have shifted distribution over time. Around 30,000 BP, the Joshua tree existed 225 miles farther south at elevations 200-300 m (656-984 ft) below present ones (George 1998).

Habitat Associations: Joshua trees are found in open desert scrub, creosote scrub, Joshua tree woodland, pinyon-juniper woodland, and in desert grassland habitats (Stark 1966, Brown 1982, Keeley and Meyers 1985, Tirmenstein 1989). They are associated with desert plains, alluvial fans, slopes, ridges, bajadas, mesas, and foothills (Webber 1953, Stark 1966, Maxwell 1971, Tirmenstein 1989). Joshua tree woodland intergrades with desert scrub, alkali scrub, and desert succulent scrub at lower elevations and with pinyon juniper woodland and sagebrush habitats at higher elevations. Joshua trees may also be found adjacent to desert riparian and desert wash habitats (Holland 1986).

Joshua trees typically occur at low densities in open woodlands (Miller and Stebbins 1964, Kuchler 1977). While the Joshua tree is the dominant species towering over the shrub community in the Mohave ecosystem (Sawyer and Keeler-Wolf 1995), other species may coexist in the overstory, including California juniper (*Juniperus californica*), singleleaf pinyon (*Pinus monophylla*), and Mohave yucca (*Yucca schidigera*; Munz 1974, Paysen et al. 1980, Parker and Matyas 1981). Dominant species of the shrub understory may include sagebrush (*Artemisia tridentata*), blackbush (*Coleogyne ramosissima*), and creosote bush (*Larrea tridentata*) (Sawyer and Keeler-Wolf 1995).

Spatial Patterns: The primary pollinator of this species is the yucca moth (*Tegeticula synthetica*) (Keeley et al. 1984, Tirmenstein 1989, Gossard 1992). Seed dispersal agents include wind and animals, including birds that expose the Joshua tree seeds for subsequent wind dispersal (McKelvey 1938, Tirmenstein 1989) and desert rodents, which are known to cache Joshua tree seeds (Keith 1985, Tirmenstein 1989). In some areas, vegetative reproduction is also an important mode of regeneration (McKelvey 1938, Vogl 1976, Keith 1982, Conrad 1987, Tirmenstein 1989).

Conceptual Basis for Model Development: The best suitable habitat for this species in the planning area is in Joshua tree woodland, pinyon-juniper woodland, and juniper woodland habitats, between 500-2,000 m in elevation, with sagebrush, desert scrub, alkali scrub, and desert succulent scrub also providing suitable habitat.

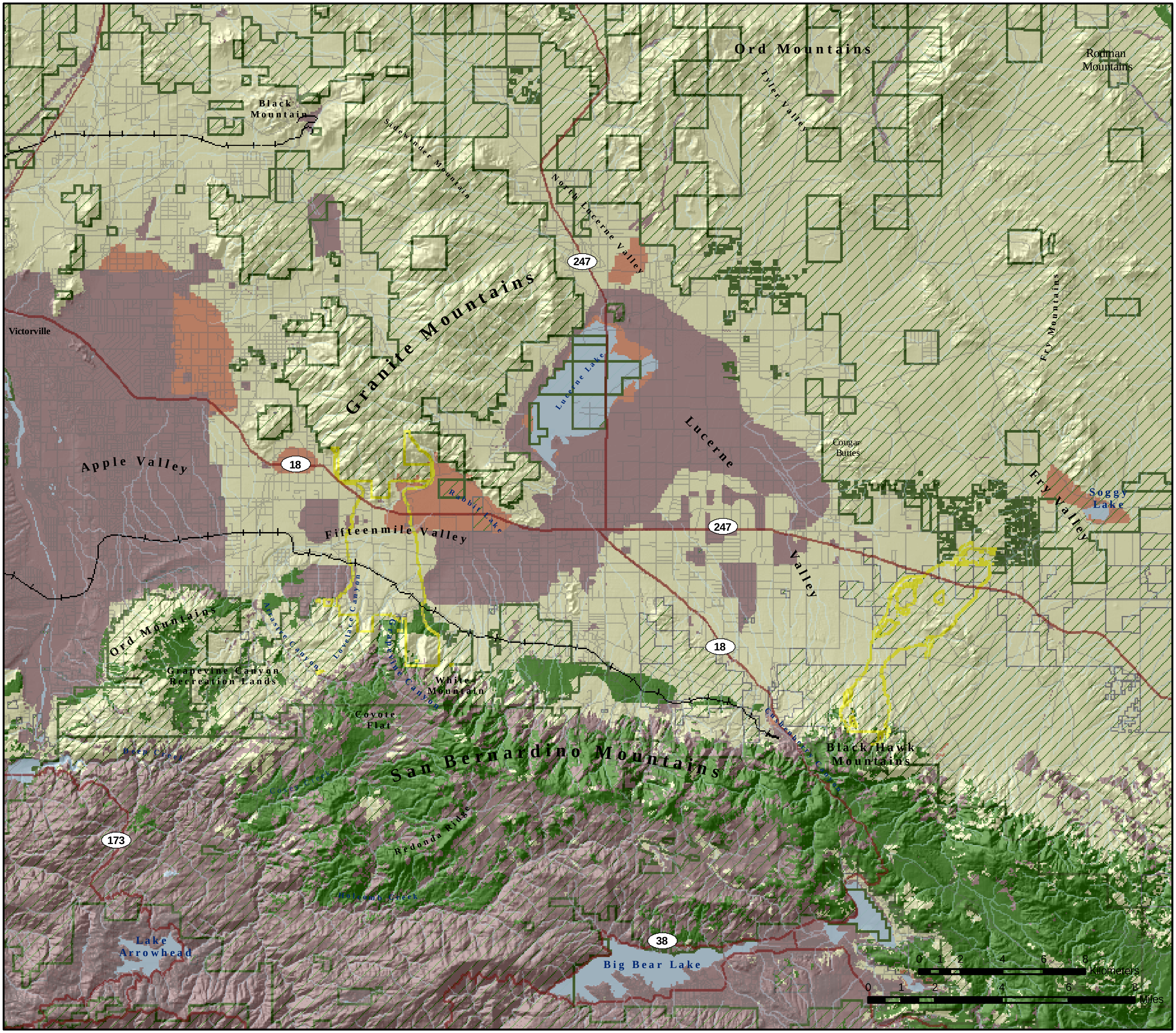
Results*:* Habitat for this Mohave endemic is widespread in the linkage planning area. Potential habitat extends from the desert facing slopes of the San Bernardino Mountains through both branches of the Least Cost Union to the targeted desert mountain ranges (Figure 36). However, the current distribution of this species in the linkage varies considerably between sites, with Joshua trees being one of the dominant plant species in the western branch of the linkage and restricted to a few individuals in the eastern branch. We conclude that the western branch of the linkage serves to connect populations of Joshua trees in the San Bernardino Mountains with those in the desert ranges.

To preserve genetic connections among Joshua tree populations, we recommend that:

- Research is conducted on the movement ecology of the yucca moth, the Joshua tree's primary pollinator.
- Further research is conducted to identify which small mammals cache Joshua tree seeds in appropriate places for germination and establishment (Esque et al. 2003).
- The effects of herbivores and drought on Joshua tree populations continue to be monitored (Esque et al. 2003).
- Collaborative management options are pursued with the BLM, USFS, CDFG and the State Lands Commission to insure the protection of Joshua tree habitats.

Figure 36.
Habitat Suitability for Joshua Tree
(Yucca brevifolia)

Degree of Suitability
- High
- Medium
- Medium to Low
- Low
- Least Cost Union
- Target Areas
- Protected Lands
- Hydrography
- Roads
- Railroads



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Linkage Design

This chapter is the heart of the report. It summarizes the goals of the Linkage Design and presents a map and description of the land within it. However, maintaining or improving linkage function requires us to also identify barriers to movement across it, including land uses that may impede movements or habitat quality for target species. Much of this chapter therefore describes existing barriers within the linkage and prescribes actions to improve linkage function.

Goals of the Linkage Design

To accommodate the full range of target species and ecosystem functions, the Linkage Design (Figure 37) should (1) provide live-in and move-through habitat for multiple species, (2) support metapopulations of smaller species, (3) ensure availability of key resources, (4) buffer against edge effects, (5) reduce contaminants in streams, (6) allow natural processes to operate, and (7) allow species and natural communities to respond to climatic changes. We elaborate on these goals below.

The Linkage Design must be wide enough to provide live-in habitat for species with dispersal distances shorter than the linkage. Harrison (1992) proposed a minimum corridor width for a species living in a linkage as the width of one individual's territory (assuming territory width is half its length). Thus, our minimum corridor width of 2 km should accommodate species with home ranges of up to about 8 km^2 (3 mi^2). This would accommodate all focal species except the largest, such as badgers and bighorn sheep. Fortunately, these species do not need live-in habitat throughout the Linkage, and should be able to move through the linkage.

The Linkage Design must support metapopulations of less vagile species. Many small animals, such as woodrats, kangaroo rats, and many invertebrates, may require dozens of generations to move between core areas. These species need a linkage wide enough to support a constellation of populations, with movements among populations occurring over decades. We believe 2 km is adequate to accommodate most target species living as metapopulations within the linkage area.

The Linkage Design was planned to provide resources for all target species, such as host plants for butterflies and pollinators for plants. For example, many species commonly found in riparian areas depend on upland habitats during some portion of their life cycle, such as some butterflies that use larval host plants in upland areas and drink from water sources as adults.

The Linkage was also designed to buffer against "edge effects" even if adjacent land becomes developed. Edge effects are adverse ecological changes that enter open space from nearby developed areas, such as weed invasion, artificial night lighting, predation by house pets, increases in opportunistic species like raccoons, elevated soil moisture from irrigation, pesticides and other pollutants, noise, trampling, and domesticated animals that attract native predators. Edge effects have been best-studied at the edge between forests and adjacent agricultural landscapes, where negative effects extend 300 m (980 ft) or more into the forest (Debinski and Holt 2000, Murcia

1995) depending on forest type, years since the edge was created, and other factors (Norton 2002). The best available data on edge effects for southern California habitats include reduction in leaf-litter and declines in populations of some species of birds and mammals up to 250 m (800 ft) in coastal scrub (Kristan et al. 2003), collapse of native plant and animals communities due to the invasion of argentine ants up to 200 m (650 ft) from irrigated areas (Suarez et al. 1998), and predation by house cats which reduce small vertebrate populations 100 m (300 ft) from the edge (K. Crooks, unpublished data). Domestic cats may affect wildlife up to 300 m (980 ft) from the edge based on home range sizes (Hall et al. 2000).

Upland buffers are needed adjacent to riparian vegetation or other wetlands to prevent aquatic habitat degradation. Contaminants, sediments, and nutrients can reach streams from distances greater than 1 km (0.6 mi) (Maret and MacCoy 2002, Scott 2002, Naicker et al. 2001), and fish, amphibians, and aquatic invertebrates often are more sensitive to land use at watershed scales than at the scale of narrow riparian buffers (Goforth 2000, Fitzpatrick et al. 2001, Stewart et al. 2001, Wang et al. 2001, Scott 2002, Willson and Dorcas 2003).

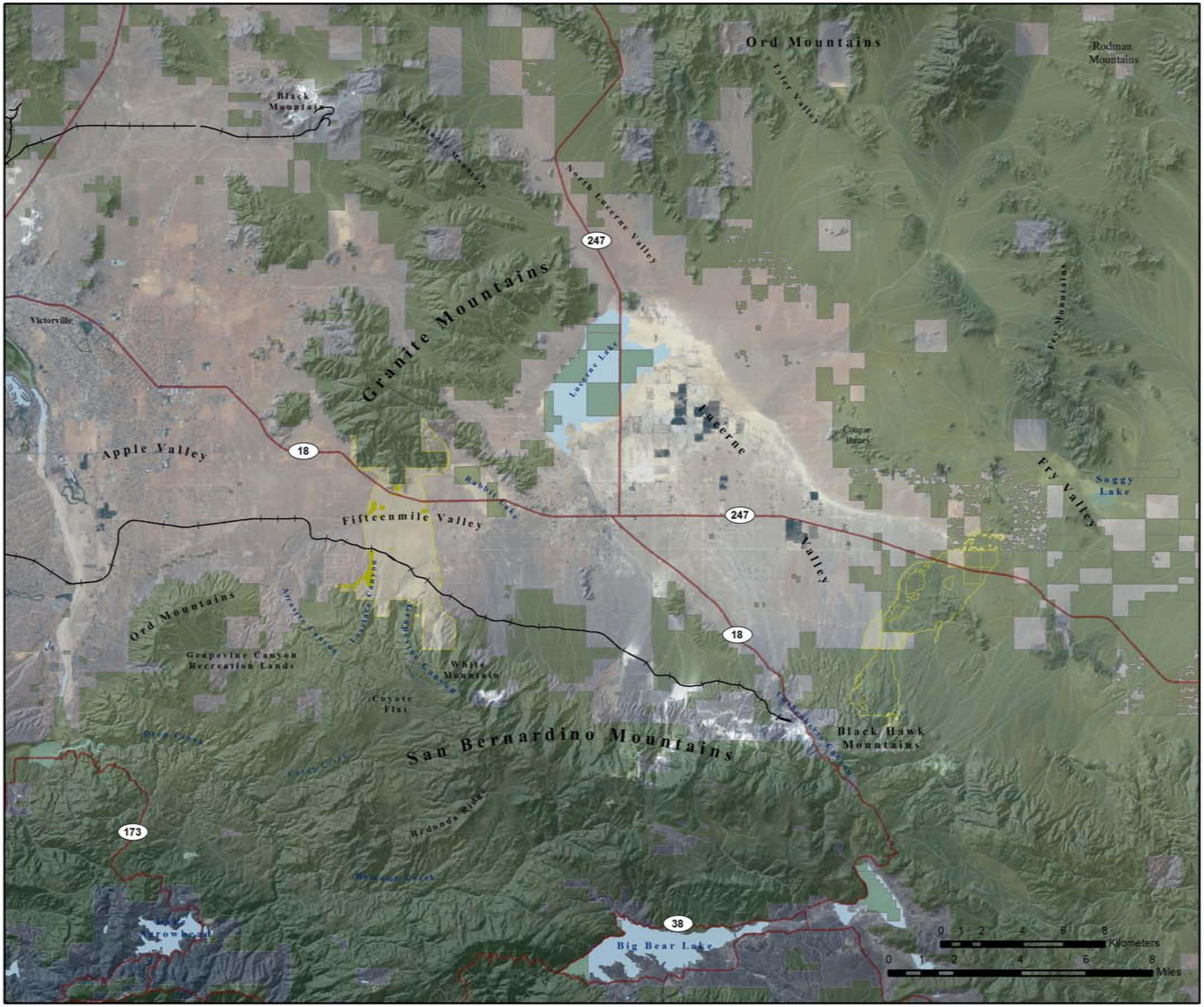
The Linkage Design must also allow natural processes of disturbance and recruitment to operate with minimal constraints from adjacent urban areas. The Linkage should be wide enough that temporary habitat impacts due to fires, floods, and other natural processes do not affect the entire linkage simultaneously. Wider linkages with broader natural communities may be more robust to changes in disturbance frequencies by human actions. Before human occupation, naturally occurring fires (due to lightning strikes) were rare in southern California (Radtke 1983). As human populations in the region soared, fire frequency has also increased dramatically (Keeley and Fotheringham 2003). Native wildlife and vegetation in the desert have evolved largely in the absence of fire, and thus are not very resilient to frequent or intensive fires. Slow-growing Joshua trees are particularly susceptible. It takes decades to replace Joshua trees lost in fires (NPCA 2005). Although fire can reduce the occurrence of exotic species in native grasslands (Teresa and Pace 1998), it can have the opposite effect in some shrubland habitats (Giessow and Zedler 1996, Brooks and Pyke 2001), encouraging the invasion of non-native plants, especially when fires are too frequent. While effects of altered fire regimes in this region are somewhat unpredictable, wider linkages with broader natural communities should be more robust to these disturbances than narrow linkages.

The Linkage Design must also allow species to respond to climate change. Plant and animal distributions are predicted to shift (generally northwards or upwards in elevation in California) due to global warming (Field et al. 1999). The linkage must therefore accommodate at least elevational shifts by being broad enough to cover an elevational range as well as a diversity of microhabitats that allow species to colonize new areas.

Description of the Linkage Design

The linkage comprises two main branches (Figure 37), which accommodate overlapping but somewhat different suites of species. The western branch (Figure 38) was delineated by the permeability analyses for bighorn sheep, badger, and Pacific kangaroo rat and includes both riparian and upland habitats. It would also serve the movement needs of such diverse species as antelope ground squirrel, desert woodrat, and

Figure 37. Linkage Design



- Linkage Design
- Stewardship Zone
- Protected Lands
- Hydrography
- Roads
- Railroads

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The eastern branch of the Linkage Design encompasses more rocky terrain (Figure 39). It was delineated by the permeability analysis for bighorn sheep but should also serve badger, antelope ground squirrel, Pacific kangaroo rat, Merriam's kangaroo rat, rock wren, and the green hairstreak butterfly. This branch extends from Black Hawk Mountain near Cushenberry Canyon in the San Bernardino Mountains, through Fry Valley to the Fry and Rodman Mountains, crossing State Highway 247 (or Old Woman Spring Road) between Lucerne and Johnson Valleys. It encompasses Joshua tree woodland and pinyon-juniper woodland in the foothills of the San Bernardino Mountains, desert scrub dominated by creosote bush through the valley and Fry Mountains, and sagebrush habitats in the Rodman Mountains. Although the eastern branch of the Linkage Design includes substantial public ownerships that protect natural habitats from development, we imposed the minimum width of 2 km in one narrow area to ensure that the functional processes of the linkage are protected. However, other uses may still threaten the integrity of these habitats and should be carefully managed on these lands. For example, use of off-road vehicles, mining, and livestock grazing can impact habitat use patterns of several species. This branch of the linkage also supports habitat for several listed and sensitive species, including the desert tortoise (CDFG 2005).

Figure 39. The eastern branch of the Linkage Design encompasses more rocky terrain and is dominated by creosote bush with a few scattered Joshua trees.

Desert scrub is by far the most common vegetation community in the linkage (Table 3), covering much of the land in the linkage and extending into the steep rugged slopes of the desert ranges.

speckled rattlesnake. It extends from the San Bernardino Mountains, encompassing both Grapevine and Lovelace canyons, through Fifteenmile Valley and across State Highway 18, to enter the Granite Mountains at Fifteenmile Point. Desert scrub is the dominant habitat type. Characteristic plant species include rabbitbrush (*Chrysothamnus nauseosus*) and Mormon tea (*Ephedra nevadensis*), with Joshua tree (*Yucca brevifolia*), Mojave yucca (*Y. schidigera*), and various chollas (*Opuntia* spp.) interspersed, thus providing suitable habitat for such focal species as Merriam's kangaroo rat, cactus wren, and metalmark butterfly. There is little surface water in the linkage, but Grapevine Canyon flows out of the San Bernardino Mountains through a dense riparian forest dominated by cottonwood (*Populus fremontii*) and various willow species (*Salix* spp.) before emptying into a broad bajada in Fifteenmile Valley. Characteristic species along the wash include desert willow (*Chilopsis linearis*), catclaw acacia (*Acacia greggii*), and mulefat (*Baccharis salicifolia*). In addition to facilitating movements for several focal species, this branch of the linkage supports habitat for several listed and sensitive species, including the Mojave ground squirrel (CDFG 2005).

Figure 38. The western branch of the Linkage Design is dominated by desert scrub with Joshua trees and several chollas interspersed.

Table 3. Approximate Vegetation and Land Cover in the Linkage Design

	Total Area Linkage Design		Area Protected in Linkage		% Protected	% of Total Area
Vegetation Name	***acre***	***hectare***	***acre***	***hectare***		
Desert Scrub	10356	4191	4180	1692	40	0.9146
Alkali Desert Scrub	525	212	0	0	0	0.0463
Juniper	276	112	0	0	0	0.0243
Pinyon-Juniper	125	50	70	28	56	0.0110
Mixed Chaparral	33	13	20	8	61	0.0029
Barren	6	2	1	0.40	17	0.0005
Agriculture	1	0.40	1	0.40	100	0.0001
Total	***11322***	***4580***	***4272***	***1729***	***38***	***100***

The final Linkage Design encompasses 4,580 ha (11,322 ac), of which approximately 38% (1,729 ha or 4,272 ac) currently enjoys some level of conservation protection, mostly BLM lands in the eastern branch of the linkage. In addition, 91 ha (224 ac) that are not included in the totals above, have already been converted to rural residential uses and were designated as stewardship zones (areas where land stewardship should be encouraged). Finally, the Linkage Design is within the California Desert Conservation Area and is addressed by the West Mojave Plan (BLM 2003, 2005).

Removing and Mitigating Barriers to Movement

Four types of features impede species movements through the Linkage: roads, railroads, residential development, and recreational activities. This section describes these impediments and suggests where and how their effects may be minimized to improve linkage function.

For most species, State Highways 18 and 247 are the most obvious barriers between protected areas in the San Bernardino Mountains and the Granite, Ord, and Rodman ranges. BLM land abuts both sides of State Highway 247 for approximately 4 km in the eastern branch of the linkage. This discussion therefore focuses on structures to facilitate movement of terrestrial species across roads, and on structures to facilitate stream flow under roads. Although some documents refer to such structures as “corridors” or even “linkages,” we use these terms in their original sense to describe the entire area required to link the landscape and facilitate movement between large protected core areas. Crossing structures represent only small portions, or choke points, within an overall habitat linkage or movement corridor. Investing in specific crossing structures may be meaningless if other essential components of the linkage are left unprotected. Thus it is essential to keep the larger landscape context in mind when discussing proposed structures to cross movement barriers, such as State Highways 18 and 247. This broader context also allows awareness of a wider variety of restoration options for maintaining functional linkages. Despite the necessary emphasis on crossing structures in this section, we urge the reader keep sight of the primary goal of conserving landscape linkages to promote movement between core areas over broad spatial and temporal scales.

Roads as Barriers to Upland Movement: Wildland fragmentation by roads is increasingly recognized as one of the greatest threats to biodiversity (Noss 1983, Harris 1984, Wilcox and Murphy 1985, Wilcove et al. 1986, Noss 1987, Reijnen et al. 1997, Trombulak and Frissell 2000, Forman and Deblinger 2000, Jones et al. 2000, Forman et al. 2003). Roads kill animals in vehicle collisions, create discontinuities in natural vegetation (the road itself and induced urbanization), alter animal behavior (due to noise, artificial light, human activity), promote invasion of exotic species, and pollute the environment (Lyon 1983, Noss and Cooperrider 1994, Forman and Alexander 1998). Roads also fragment populations by acting as semi-permeable to impermeable barriers for non-flying animals (e.g., insects, fish, amphibians, reptiles, and mammals) and even some flying species (e.g., butterflies and low-flying birds). Roads may even present barriers for large mammals such as bighorn sheep (Rubin et al. 1998). The resulting demographic and genetic isolation increases extinction risks for populations (Gilpin and Soulé 1986). For example Ernest et al. (2003) has documented little flow of mountain lion genes between the Santa Ana and Palomar ranges (where I-15 is the most obvious barrier), and between the Sierra Madre and Sierra Nevada (where I-5, and urbanization along SR-58, are the most obvious barriers). Fragmentation also results in smaller populations, which are more susceptible to extinction due to demographic and environmental stochasticity.

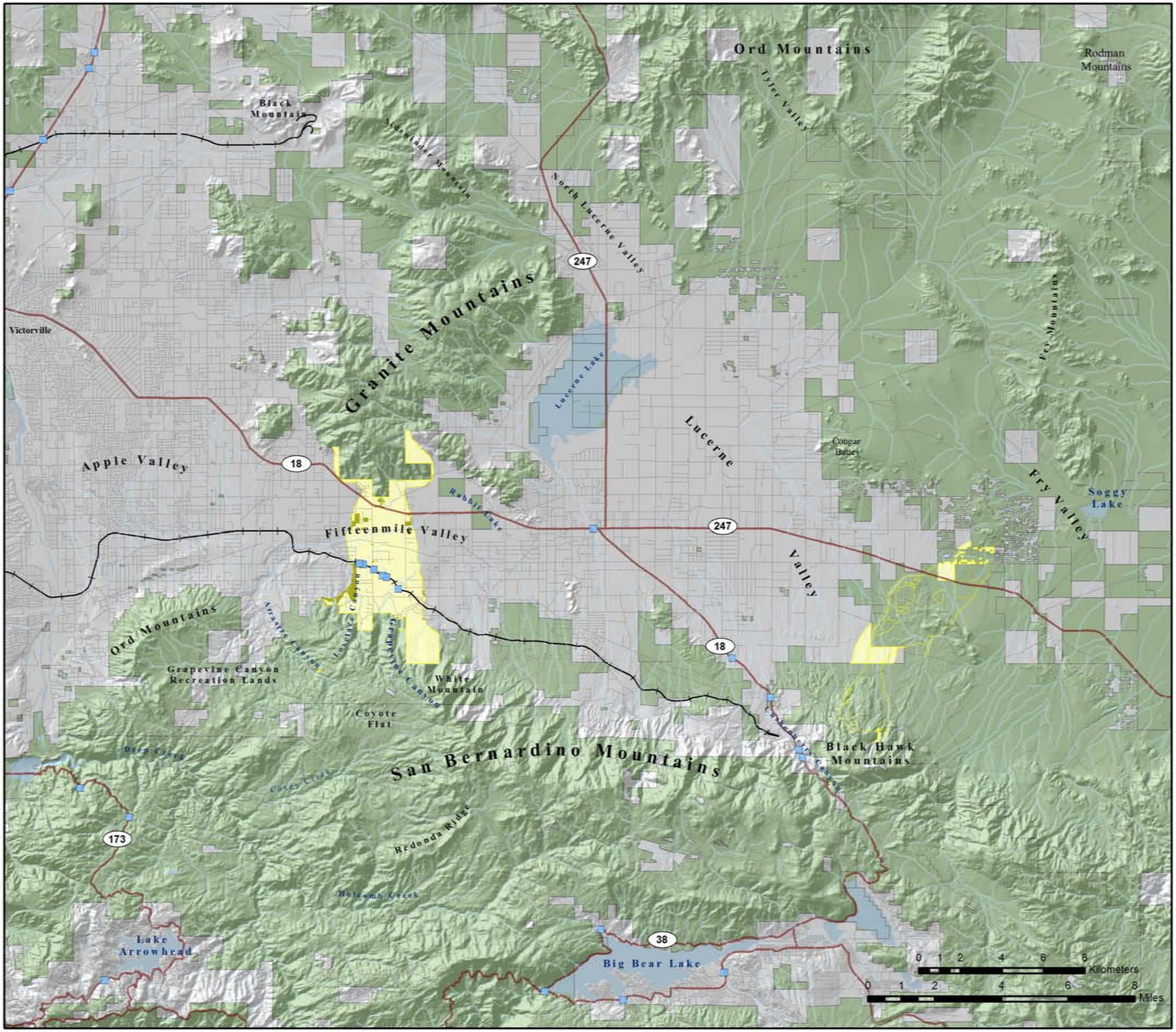
The impact of a road on animal movement varies with species, context (vegetation and topography near the road), and road type and level of traffic (Clevenger et al. 2001). For example, a road on a stream terrace can cause significant population declines in amphibians that move between uplands and breeding ponds (Stephenson and Calcarone 1999), but a similar road on a ridgeline may have negligible impact. Most documented impacts on animal movement concern paved roads. Dirt roads may actually facilitate movement of some species, such as mountain lions (Dickson et al. 2004), while adversely impacting other species, such as snakes that sun on them and may be crushed even by infrequent traffic.

Roads in the Linkage Design: At the time of this report, there are only 5.3 km (3.4 mi) of paved roads in the Linkage Design and 71 km (44 mi) of dirt roads (Table 4). State Highway 18 (Happy Trails Highway) and Highway 247 (Old Woman Spring Road) are the only major transportation routes crossing the linkage and the only paved roads (Figure 40). State Highway 18 bisects the western branch of the linkage and State Highway 247 crosses the eastern branch. In 1993, Average Daily Traffic was 3,000 - 35,000 vehicles for State Highway 18 and 1,300 - 15,000 vehicles for State Highway 247 (http://www.cahighways.org). These highways are currently 1 lane in each direction and entirely at grade. No existing structures (i.e., bridges, pipes, or culverts) were incorporated into the original road design (Figure 40).

Table 4. Major transportation routes in the Linkage Design.

Road Name	**Length (km)**	**Length (mi)**
State Highway 18	2.7	1.7
State Highway 247	2.6	1.7
Total length Paved Roads	**5.3**	**3.4**
Total length Dirt Roads	71	44
Total Roads	**76.3**	**47.4**

Figure 40.
Existing Infrastructure in the Planning Area



- Linkage Design
- Stewardship Zone
- Protected Lands
- Hydrography
- Highways
- Secondary Roads
- Railroads
- Potential Crossing Structures

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Types of Mitigation for Roads: Forman et al. (2003) suggest several ways to minimize the impact of roads on linkages by creating wildlife crossing structures and reducing traffic noise and light, especially at entrances to crossing structures. Wildlife crossing structures have been successful both in the United States and in other countries, and include underpasses, culverts, bridges, and bridged overcrossings. Most structures were initially built to accommodate streamflow, but research and monitoring have also confirmed the value of these structures in facilitating wildlife movement. The main types of structures, from most to least effective, are vegetated land-bridges, bridges, underpasses, and culverts.

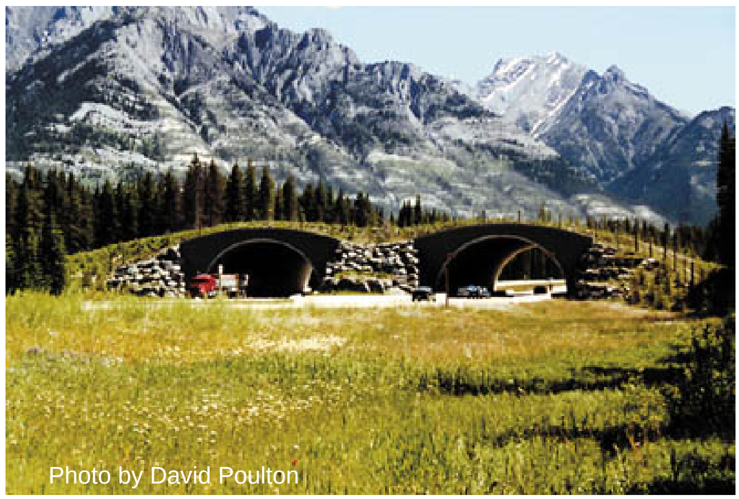

Figure 41. An example of a vegetated land bridge built to enhance movement of wildlife populations

There are approximately 50 vegetated wildlife overpasses (Figure 41) in Europe, Canada, and the U.S. (Evink 2002, Forman et al. 2003). They range from 50 m (164 ft) to more than 200 m (656 ft) in width (Forman et al. 2003). Soil depths on overpasses range from 0.5 to 2 m, allowing growth of herbaceous, shrub, and tree cover (Jackson and Griffin 2000). Wildlife overpasses can maintain ambient conditions of rainfall, temperature, light, vegetation, and cover, and are quieter than underpasses (Jackson and Griffin 2000). In Banff National Park, Canada, large mammals preferred overpasses to other crossing structures (Forman et al. 2003). Similarly, woodland birds used overpasses significantly more than they did open areas without an overpass. Other research indicates overpasses may encourage birds and butterflies to cross roads (Forman et al. 2003). Overpass value can be increased for small, ground-dwelling animals by supplementing vegetative cover with branches, logs, and other cover (Forman et al. 2003).

Bridges over waterways are also effective crossing structures, especially if wide enough to permit growth of both riparian and upland vegetation along both stream banks (Jackson and Griffin 2000, Evink 2002, Forman et al. 2003). Bridges with greater openness ratios are generally more successful than low bridges and culverts (Veenbaas and Brandjes 1999, Jackson and Griffin 2000). The best bridges, termed *viaducts* (Figure 42), are elevated roadways that span entire wetlands, valleys, or gorges, but are cost-effective only where topographic relief is sufficient to accommodate the structure (Evink 2002).

Although inferior to bridges, culverts can be effective crossing structures for some species (Jackson and Griffin 2000). Only very large culverts are effective for carnivores and other large mammals (Figure 43). Gloyne and Clevenger (2001) suggest that underpasses for ungulates should be at least 4.27 m high and 8 m wide, with an openness ratio of 0.9 (where the openness ratio = height x width/length). Earthen flooring is preferable to concrete or metal (Evink 2002).

For rodents, pipe culverts (Figure 44), about 1 ft in diameter without standing water are superior to large, hard-bottomed culverts, apparently because the overhead cover makes small mammals feel secure against predators (Forman et al. 2003, Clevenger et al. 2001). In places where a bridged, vegetated undercrossing or overcrossing is not feasible, placing pipe culverts alongside box culverts can help serve movement needs of both small and large animals. Special crossing structures that allow light and water to enter have been designed to accommodate amphibians (Figure 45). Retaining walls should be installed, where necessary, along paved roads to deter small mammals, amphibians, and reptiles from accessing roadways (Jackson and Griffin 2000). Concrete retaining walls are relatively maintenance free, and better than wire mesh, which must

Figure 42. A viaduct in Slovenia built to accommodate wildlife, hydrology, and human connectivity.

Figure 43. Arched culvert on German highway, with rail for amphibians and fence for larger animals.

Figure 44. Pipe culvert designed to accommodate small mammals.

Figure 45. Amphibian tunnels allow light and moisture into the structure.

be buried and regularly maintained.

Noise, artificial night lighting, and other human activity can deter animal use of a crossing structure (Yanes et al. 1995, Pfister et al. 1997, Clevenger and Waltho 1999, Forman et al. 2003), and noise can deter animal passage (Forman et al. 2003). Native shrub or tree cover should occur near the entrance of structures (Evink 2002); however, the behaviors of individual focal species should carefully be considered. For example, bighorn sheep might avoid dense vegetation (USFWS 2000). Existing structures can be substantially improved with little investment by installing wildlife fencing, earthen berms, and vegetation to direct animals to passageways (Forman et al. 2003). Regardless of crossing type, wildlife fencing is necessary to funnel animals towards road crossing structures and keep them off the road surface (Falk et al. 1978, Ludwig and Bremicker 1983, Feldhammer et al. 1986, Forman et al. 2003). Earthen one-way ramps can allow animals that wander into the right of way to escape over the fence (Bekker et al. 1995, Rosell Papes and Velasco Rivas 1999, Forman et al. 2003).

Recommended Crossing Structures on State Highways 18 and 247: State Highways 18 and 247 are both currently at grade for their entire length. Opportunities for using natural topographic features to enhance habitat connectivity in the linkage are limited and no crossing structures currently exist. The speed limit is 55 mph along both stretches of highway in the linkage, but many vehicles far exceed this limit. Although flat desert highways seem to be destined for high speeds, we suggest reducing the speed limit on both highways to 45 mph through each 2.6 km (1.7 mi) branch of the linkage. This is the simplest and most cost effective way to reduce wildlife/vehicle collisions (Bertwistle 1999). We also recommend installing wildlife crossing signs to alert drivers they are entering a wildlife movement corridor. Laser and infrared activated warning signs with flashing lights have been used to alert drivers to slow down for wildlife (Reed 1981, Messmer et al. 2000, Gordon 2001, Robinson et al. 2002, Huijser and McGowen 2003). The systems flashing lights are activated when wildlife step over the sensing device on the approach to the monitored roadway (Gordon 2001). These two actions alone could significantly reduce wildlife mortality in the linkage area but other measures can be taken to improve wildlife movement when the next highway improvement projects are undertaken.

Future transportation improvement projects will likely widen both of these 2-lane highways to at least 4 lanes. The Lucerne Valley Chamber of Commerce supports widening State Highway 18 to 4 lanes and/or installing left-turn lane pockets (http://www.lucernevalley.org/chamber/lveda.htm). These transportation improvement projects represent timely opportunities for incorporating wildlife-crossing structures into the road design to improve habitat connectivity. We suggest a roadkill study as part of the upgrade projects, with design of crossing structures contingent on results.

In the western branch of the linkage (Figure 46), we recommend burying or elevating a stretch of State Highway 18 at least 200 m long to provide an at-grade wildlife crossing that conforms to the natural topography of the site. To either side of this structure, we suggest installing several pipe culverts (1 ft diameter), spaced fairly frequently to provide for passage of small mammals and reptiles. The western branch of the linkage was delineated by the permeability analyses for Nelson's bighorn sheep, American badger, and Pacific kangaroo rat. We recorded a number of species during field surveys, including coyote, bobcat, antelope ground squirrel, and cactus wren, via visual observation or diagnostic sign. In addition, a well-worn network of small mammal trails and burrows was found throughout the linkage area. Surface water is very scarce in the linkage, so the riparian habitat in Grapevine Canyon draws animals into the drainage. However, this area is also popular with off-road vehicle enthusiasts, with heavy signs of use in the wash. These activities impact soils and vegetation and likely inhibit species from using this canyon. We highly recommend preventing off-road vehicles from entering the wash, and we endorse enforcing closures to maintain the wild character of Grapevine Canyon.

Figure 46. State Highway 18 in the western branch of the linkage, looking south toward Grapevine and Lovelace canyons in the San Bernardino Mountains from Fifteenmile Point in the Granite Mountains. We recommend burying or elevating a stretch of the highway at least 200 m wide to provide an at-grade wildlife crossing that conforms to the natural topography of the site.

BLM has already protected most of the eastern branch of the linkage, including a 3-km (1.9-mi) stretch along this section of State Highway 247 (Figure 47). This branch of the linkage was delineated primarily by the permeability analysis for bighorn sheep, but several other focal species that use desert scrub habitat would also benefit from this connection. Bighorn sheep prefer overpasses to underpasses (Forman et al. 2003). If wildlife movement studies for road improvement projects confirm bighorn sheep movement through this area, we recommend installing a vegetated overpass over State Highway 247. Although the topography in this area isn't well-suited to accommodate a ridge-to-ridge overpass, there is a ridge south of the highway that could be extended out and over the highway (Figure 47), using a structure similar to that shown in Figure 41. The structure should be at least 200 to 300 m (656 to 984 ft) wide and should be strong enough to allow placement of large boulders along each side of the overpass to minimize noise from the highway, with a soil depth sufficient to maintain desert vegetation. The overpass should be vegetated using plants propagated from cuttings and seed collected in the surrounding vegetation. We also recommend installing pipe culverts on either side of this structure to provide for movement of small mammals and reptiles.

Figure 47. Land administered by BLM along State Highway 247 in the eastern branch of the linkage. The ridge south of the highway could be extended out and over the highway providing an overpass for wildlife and a tunnel for vehicular traffic. The ridge currently extends to within roughly 300 m of the existing highway.

Other Recommendations Regarding Paved Roads within the Linkage Design:

- Encourage woody vegetation leading up to both sides of crossing structures to provide cover for wildlife and to direct their movement toward the crossing structure. Work with the USFS, BLM, California Native Plant Society, local Resource Conservation District, or other non-profit organizations to restore vegetative cover at passageways. However, crossing structures designed primarily for bighorn sheep should not be heavily vegetated, but should mimic vegetation composition and structure of nearby bighorn sheep habitat.

- Where appropriate, install wildlife fencing along the freeway to guide animals to crossing structures and keep them off the highway.

- Use short retaining walls or fine mesh fencing to guide reptiles to crossing structures.

- On freeways and other paved roads, minimize artificial night lighting, and direct the light onto the roadway and away from adjacent wildland.

Although these portions of State Highways 18 and 247 are not currently impermeable barriers, especially at night, permeability for most species is likely to be lost if further subdivision and home-building occurs here. We recommend maintaining the rural character of the landscape with appropriate measures to confine light and noise pollution to home sites. We strongly recommend purchase or conservation easements for key parcels and attention to wildlife connectivity during any upgrading of these highways.

Roads as Ephemeral Barriers: Structures designed for wildlife movement are increasingly common. In southern California, 26 wildlife crossing structures were installed along 22-miles of State Highway 58 in the Mohave Desert specifically for desert tortoise movement (Evink 2002). In the South Coast Ecoregion, the Coal Canyon interchange on State Highway 91 has been converted, through a partnership with CalTrans, California State Parks, and Hills for Everyone, from a vehicle interchange into a wildlife underpass to facilitate movement between the Chino Hills and the Santa Ana Mountains. About 8 wildlife underpass bridges and viaducts were installed along State Highway 241 in Orange County, although urbanization near this toll road has compromised their utility (Evink 2002). Elsewhere, several crossing structures, including 3 vegetated overpasses, have been built to accommodate movement across the Trans-Canada Highway in Banff National Park (Clevenger et al. 2001). In south Florida, 24 underpasses specifically designed for wildlife were constructed along 64km (38 mi) of Interstate 75 in south Florida in about 1985. The structures are readily used by endangered Florida panthers and bears, and have reduced panther and bear roadkill to zero on that route (Land et al. 2001). Almost all of these structures were retrofitted to existing highways rather than part of the original road design. This demonstrates that barrier or filter effects of existing roads are at least partially reversible with well-designed improvements.

Representatives from CalTrans have attended Missing Linkages workshops, and the agency is incorporating wildlife crossing improvements into its projects, with a focus in important linkage areas. For example, CalTrans recently proposed building a wildlife overpass over SR-118, and in February 2003 CalTrans started removing pavement from the Coal Canyon interchange in Orange County and transferred the property to California State Parks expressly to allow wildlife movement between Cleveland National Forest and Chino Hills State Park. Since then, habitat restoration efforts have been initiated in Coal Canyon and wildlife movement continues to be monitored.

Rail Line Barriers to Movement

Railroads also can impede plant and animal movement (Messenger 1968, Niemi 1969, Klein 1971, Stapleton and Kiviat 1979, Muehlenbach 1979, Lienenbecker and Raabe 1981, Forman 1995), although probably less so than highways. Roadkill rates are likely a great deal lower per train than per vehicle on roads, though trains have been derailed from collisions with large mammals (Forman and Boerner 1981, Forman et al. 2003). Grain spilled from trains can attract deer and bears to feed on the rail line; such events have caused significant mortality to grizzly bears in Montana (Federal Register Feb 11

2004. 69: 6683-6685; C. Servheen, University of Montana, personal communication). Freight trains transporting cargo also disperse non-native seeds, insects, and perhaps small mammals along railroad networks (Thomson 1940, Stapleton and Kiviat 1979, Forman et al. 2003).

Existing Rail Lines in the Linkage Design Area: The western branch of the linkage is bisected by the Atchison, Topeka, and Santa Fe Railroad about 3 to 4 km (2 to 2.5 mi) south of State Highway 18 and just outside the boundary of Grapevine Canyon National Recreation Area. The railroad runs along the entire length of the north slope of the San Bernardino Mountains, terminating near Cushenberry Canyon. The railroad likely services the mining operations in this area. For much of its length, the railroad tracks lie on a bed of gravel approximately 2 m (6 ft) high. For some small mammals and reptiles, the rail lines and expanse of gravel may present modest impediments to movement, although there are multiple crossing points under the railroad tracks.

Figure 48. Numerous pipe culverts occur beneath the railroad tracks.

There are several structures under the rail line that may accommodate wildlife movement. Most are pipe culverts (Figure 48), while the main channel of Grapevine Canyon is bridged (Figure 49). Pairs of corrugated metal pipe culverts are spaced about every ¼ mile and each measures roughly 1 m (3 ft) in diameter and 15 m (49 ft) long. The bridge over the river has 7 chambers with each section measuring about 4 m (13 ft) wide, 1.5 to 9 m (5 to 30 ft) high, and 6 m (20ft) long.

Figure 49. The only bridge in the linkage spans Grapevine Canyon and was built for the railroad.

Recommendations to Minimize the Effects of Rail Lines in the Linkage Design: We believe that the existing rail line presents a moderate impediment to movement for some small mammals and reptiles. Although the railroad is probably not a complete barrier, in concert with nearby State Highways 18 and 247, it reduces connectivity in the linkage area. We recommend that any future railroad realignments or upgrades be used as opportunities to improve wildland connectivity. Similar crossing solutions work for railroads as for roads (Reed and Schwarzmeier 1978, Borowske and Heitlinger 1981, Forman 1995). If railroad improvement projects are undertaken, we recommend: (1) maintaining or increasing the dimensions of the existing bridge over Grapevine Canyon; (2) upgrading the existing pipe culverts to concrete box culverts with natural substrate flooring; and (3) installing additional 1-ft diameter pipe culverts at frequent intervals for small mammals and reptiles.

Other Land Uses that Impede Utility of the Linkage

Land management policies in the protected areas and the linkage can substantially impact habitat and movements of species through the Linkage Design area. It is essential that major land management and planning entities (e.g., USFS, BLM, CDFG, and San Bernardino County) integrate the linkage plan into their policies and regulations.

Urban Barriers to Movement

Urban development, unlike roads or aqueducts, creates barriers that cannot be corrected by building crossing structures. Urban and suburban areas make particularly inappropriate landscapes for movements of most plants and animals (Marzluff and Ewing 2001). In addition to direct habitat removal, urban development creates edge effects that reach well beyond the development footprint. Most terrestrial mammals that move at night will avoid areas with artificial night lighting (Beier, in press). Pet cats can significantly depress populations of small vertebrates near housing (Churcher and Lawton 1987, Crooks 1999, Hall et al. 2000). Irrigation of landscapes surrounding homes encourages the spread of Argentine ant populations into natural areas, where they cause a halo of local extinctions of native ant populations extending about 200 m (650 ft) or more into native vegetation (Suarez et al. 1998, Bolger et al. 2000). Similar affects have been documented for amphibians (Demaynadier and Hunter 1998). Habitat disturbance caused by intense human activity (e.g., off-road vehicle use, dumping, camping and gathering sites) also tends to rise in areas surrounding urban developments. Areas disturbed by human use show decreases in bird and small mammal populations (Sauvajot unpubl., Crooks et al. 2004).

Urban Barriers in the Linkage Design Area: Topography, habitat, water supplies and other natural constraints limit opportunities for significant population growth in both branches of the linkage, but any increase in urbanization in the Linkage Design could seriously compromise wildland connectivity. Existing development in the area is limited to the western branch of the linkage and includes a few houses and a salvage yard involving vehicular debris at Fifteenmile Point at the base of the Granite Mountains. The growing communities of Apple Valley and Lucerne Valley border the western branch. Lucerne Valley also borders the eastern branch of the linkage. The city of Apple Valley is fairly impermeable to wildlife movement due to high-density development, high traffic volume, large numbers of pets, and light and noise pollution, while some areas of Lucerne Valley remain somewhat permeable. Cooperation with existing and future residents in the area is essential to the functionality of the linkage, to limit impacts of lighting, roads, domestic livestock, pets, and traffic on wildlife movement in the linkage.

Examples of Mitigation for Urban Barriers: Urban developments, unlike roads, create movement barriers that cannot be readily removed, restored, or mitigated. Preventing urban developments in key areas through acquisition or conservation easements is therefore the strongest option. Mitigation for existing urban developments focuses on designing and managing buffers to reduce penetration of undesirable effects into natural areas (Marzluff and Ewing 2001). Management in buffers can include fencing in pets, reducing human traffic in sensitive areas or constriction points, limiting noise and lighting, reducing traffic speeds, minimizing use of irrigation, encouraging the planting of local native vegetation, minimizing the use of pesticides, poisons and other harmful chemicals, and increasing enforcement of existing regulations.

Recommendations for Mitigating the Effects of Urban Barriers in the Linkage Design Area: We recommend the following mitigation actions for urban, suburban, and rural developments in the Linkage Design area:

- Encourage land acquisition and conservation easements with willing private landowners in the Linkage Design.
- Encourage homes abutting the linkage area to have minimal outdoor lighting, directed toward the home and yard rather than into the linkage. Homeowners should use fences to keep dogs and domestic livestock from roaming into the linkage area. Residents should be encouraged to keep cats indoors at all times.
- Increase and maintain high water quality standards. Work with the Resource Conservation District to help establish use of Best Management Practices for rural communities in the Linkage Design and surrounding communities.
- Support efficient water use and education programs that promote water conservation (County of San Bernardino 2005).
- Support the protection of riparian and adjacent upland habitats on private lands. Pursue cooperative programs with landowners to improve conditions in riparian and upland habitats on private land in the Linkage Design.
- Develop a public education campaign, such as the On the Edge program developed by the Mountain Lion Foundation (www.mountainlion.org), which encourages residents at the urban wildland interface to become active stewards of the land by reducing penetration of undesirable effects into natural areas. Topics addressed include living with wildlife, predator-safe enclosures for livestock and pets, landscaping, water conservation, noise and light pollution.
- Work with San Bernardino County and the communities of Apple and Lucerne Valleys to discourage major new residential or urban developments in key areas of the Linkage Design.

Recreation

Recreational use is not inherently incompatible with wildlife movement, although, intense recreational activities have been shown to cause significant impacts to wildlife and plants

(Knight and Cole 1995). Areas with high levels of off-road vehicle use are more readily invaded by invasive plant species (Davidson and Fox 1974), accelerate erosion and reduce soil infiltration (Iverson 1980), and alter habitat use by vertebrates (Brattstrom and Bondello 1983, Nicolai and Lovich 2000). Even such relatively low-impact activities as wildlife viewing, hiking, and horse back riding have been shown to displace wildlife from nutritionally important feeding areas and prime nesting sites (Anderson 1995, Knight and Cole 1995). The increased time and energy spent avoiding humans can decrease reproductive success and make species more susceptible to disease (Knight and Cole 1995). In addition, humans, horses, and pets can carry seeds of invasive species into natural areas (Benninger 1989, Benninger-Traux et al. 1992).

Recreation in the Linkage Design Area:

USFS and BLM lands provide a wide range of recreational opportunities, from nature-based dispersed recreational activities (e.g., hiking, backpacking, bird watching) to high-density recreation in developed sites. The majority of recreational use is concentrated in developed facilities with road access. Recreational activities in the vicinity of the linkage include birding, hiking, camping, horseback riding, off-road vehicle use, and target shooting. A high-density network of off-road vehicle routes have been designated along the northern slope of the San Bernardino Mountains in the Juniper Flats, Grapevine Canyon, and Bighorn Mountain areas. No designated routes occur in the western branch of the linkage or in the Granite Mountains area but there are a few designated routes in the eastern branch of the linkage, both north and south of Highway 247 in the Johnson Valley OHV Area (U.S. Department of the Interior 2003). However, unauthorized road and trail creation (i.e., hill climbs and secondary trails up several side canyons) is also high on USFS and BLM lands. Target shooting is another recreational activity, with many spent shells noted during field investigations in Grapevine Canyon. The West Mojave Plan has proposed construction of parking and staging facilities for equestrian and recreational users in the Grapevine Canyon area that would increase access to and use of this area.

Examples of Mitigation for Recreational Impacts: If recreational activities are effectively monitored, most negative impacts can be avoided or minimized by limiting types of use, directing recreational activities away from particular locations, sometimes only for particular seasons, and with reasonable precautions.

Recommendations to Mitigate the Effects of Recreation in the Linkage Design Area: We provide the following initial recommendations to prevent or minimize negative effects of recreation in the Linkage Design area:

- Enforce existing regulations and monitor trail development and recreational uses (e.g., off-road vehicles, target shooting) to provide a baseline for decisions regarding levels, types, and timing of recreational use.

- Work with regional monitoring programs, such as the State's Resource Assessment Program, to collect information on special status species, species movements, and vegetation disturbance in areas of high recreational activity.

- Work with the BLM, USFS, and non-governmental organizations to develop and conduct on-the-ground, multi-lingual outreach programs to recreational users on how to lessen impacts in sensitive riparian areas.

- Close roads and trails that pass through known bighorn sheep lambing areas during the reproductive season and protect critical water sources from disturbance during the summer (Holl and Bleich 1983, Papouchis et al. 2001, USFWS 2001).

- Prohibit new off-road vehicle routes within bighorn sheep habitat (USFWS 2001).

- Prevent off-road vehicles from driving in riparian areas and washes (e.g., Grapevine Canyon) and enforce closures. Review existing regulations relative to linkage goals and develop additional restrictions or recommend closures in sensitive areas.

- Close, obliterate, and restore to natural habitat any unauthorized off-road vehicle routes and enforce closures. Discourage designation of any new off-road routes in the linkage.

- Encourage hunters, target shooters, and plinkers to use nontoxic alternatives to lead shot.

- Enforce leash laws (USFWS 2001, Holl et al. 2004).

Land Protection & Stewardship Opportunities

A variety of conservation planning efforts is currently underway in the Linkage Design area. The South Coast Missing Linkages Project supports these efforts by providing information on linkages critical to achieving their conservation goals at a landscape scale. This section provides information on planning efforts, agencies, and organizations that may represent opportunities for conserving the San Bernardino – Granite Mountains Connection. This list is not exhaustive, but provides a starting point for persons interested in becoming involved in preserving and restoring linkage function.

Bureau of Land Management: BLM sustains the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations. BLM administers all of the targeted protected areas in the Granite, Ord, and Rodman Mountains, about a 3-km stretch of land along State Highway 247 in the eastern branch of the linkage that joins the San Bernardino Mountains to the desert ranges, and National Recreation Lands in the San Bernardino Mountains. The West Mojave Plan recently completed by BLM outlines several conservation strategies for the linkage planning area (see below). Representatives from BLM have attended each of the South Coast Missing Linkages workshops. For more information on lands administered by the BLM, visit http://www.ca.blm.gov.

California Department of Fish and Game: CDFG manages California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. Acquisition dollars for CDFG projects are authorized through the Wildlife Conservation Board as part of their

Concept Area Protection Plan (CAPP) process. For more information on the Department, visit their website at http://www.dfg.ca.gov.

California Department of Transportation: CalTrans strives to achieve the best safety record in the nation, reduce traveler delays due to roadwork and incidents, deliver record levels of transportation system improvements, make transit a more practical travel option, and improve the efficiency of the transportation system. CalTrans representatives have attended each of the South Coast Missing Linkages workshops and have shown leadership and a willingness to improve linkage function in the most important linkage areas. CalTrans recently proposed building a wildlife overpass over SR-118. In February 2003, CalTrans started removing pavement from the Coal Canyon interchange on SR 91 in Orange County and transferred the property to California State Parks expressly to allow wildlife movement between the Santa Ana Mountains of the Cleveland National Forest and Chino Hills State Park. To find out more about the innovative plans being developed by Caltrans, visit their website at http://www.dot.ca.gov.

California State Parks: California State Parks provides for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation, such as those available at Silverwood Lake State Park. The Department is actively engaged in the preservation of the State's rich biological diversity through their acquisition and restoration programs. Ensuring connections between State Park System wildlands and other protected areas is one of their highest priorities. CSP is involved in the Coal Canyon habitat connection restoration project to preserve mountain lion movement under SR 91 at the north end of the Santa Ana Mountains. CSP co-sponsored the statewide Missing Linkages conference and is a key partner in the South Coast Missing Linkages effort. For more information, visit their website at http://www.parks.ca.gov.

California State Parks Foundation: The Foundation is the only statewide organization dedicated to preserving, advocating and protecting the legacy of California's State Parks. The Foundation supports environmental education, wildlife and habitat preservation, volunteerism, and sound park policy. Since its inception, the Foundation has provided over $110 million for projects and educational programs while building a statewide network of park supporters. These initiatives have helped the parks acquire more land, create more trails, restore wildlife habitat, build visitor centers, construct interpretive displays, and support family camping for underserved youth. CSPF is a partner in the South Coast Missing Linkages Project. For more on their exciting programs, visit www.calparks.org.

California Wilderness Coalition: The California Wilderness Coalition builds support for threatened wild places on a statewide level by coordinating efforts with community leaders, businesspeople, decision-makers, local organizations, policy-makers, and activists. CWC was also a co-sponsor of the statewide Missing Linkages effort. For more information, visit them at http://www.calwild.org.

California Wild Heritage Campaign: The mission of the California Wild Heritage Campaign is to ensure the permanent protection of California's remaining wild public lands and rivers. Congresswoman Hilda Solis introduced the Southern California Wild

Heritage Act. The bill would significantly expand the National Wild and Scenic Rivers System and the National Wilderness Preservation System on federally managed public lands in Southern and Central California. A total of 13 new Wild and Scenic Rivers are included in the bill, totaling more than 312 miles, and 47 new Wilderness Areas and Wilderness Additions totaling 1,686,393 acres. The Campaign builds support for Wilderness and Wild and Scenic River protection by compiling a detailed citizen's inventory of California's remaining wild places; organizing local communities in support of those places; building a diverse, broad-based coalition; and educating the general public, government officials and the media about the importance of protecting California's wild heritage. For more information on the status of the Act, visit http://www.californiawild.org.

County of San Bernardino: San Bernardino County is in the process of a 2025 General Plan Update that consists of two phases, the first of which was completed in 2002. During Phase I, a strategic analysis of the 1989 General Plan and Environmental Impact Report (EIR) was conducted. Phase II is anticipated to be a 3-year process which began in mid-2003. To find out more about the General Plan Update, go to: www.sbcountygeneralplan.net, or visit the county's website at http://www.co.san-bernardino.ca.us/.

Desert Protective Council: The Desert Protective Council's mission is the protection, appreciation, and enjoyment of some of nature's most marvelous bounty: our deserts. The Council has spearheaded many hard-won successes that have resulted in the preservation of wildlife habitats and natural resources of the four great deserts of the southwest. For more information, go to http://www.dpcinc.org.

Desert Tortoise Council: The Council is a private, nonprofit organization that promotes conservation of the desert tortoise in the wild in a variety of ways. They hold an annual symposium to bring together scientists, managers, and concerned people to share the latest information available on the desert tortoise and its management. For more information, go to http://www.deserttortoise.org.

Endangered Habitats League: The Endangered Habitats League is dedicated to ecosystem protection and sustainable land use. EHL participates in regional planning to curtail sprawl and preserve intact rural and agricultural landscapes. It actively supports the revitalization of urban areas and the development of vibrant community centers, effective mobility, and affordable housing choices. For more information, visit them at http://www.ehleague.org.

Environment Now: Environment Now is an active leader in creating measurably effective environmental programs to protect and restore California's environment. Since its inception, the organization has focused on the preservation of California's coasts and forests, and reduction of air pollution and urban sprawl. Environment Now uses an intelligent combination of enforcement of existing laws, and application of technology and process improvements to eliminate unsustainable practices. To find out more about their programs, visit their website at http://www.environmentnow.org

Joshua Tree Tortoise Rescue: This non-profit organization is permitted by the State of California Department of Fish and Game to rescue and rehabilitate the endangered

California desert tortoise. Their mission is dedicated to the survival of the desert tortoise through education and adoption programs. For more information visit http://www.desertgold.com/tort/tort.html.

National Park Service: The purpose of the National Park Service is "...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." NPS is a key partner in the South Coast Missing Linkages Project. For more on the National Park Service, see http://www.nps.gov.

Regional Water Quality Control Board: The State WQCB strives to preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations. The RWQCB oversees waters in the Linkage Design area. For more information, visit their website at http://www.swrcb.ca.gov.

Resource Conservation Districts (RCD): The Mojave Desert RCD is the federal district responsible for this area. This non-profit agency supports conservation of natural ecosystems through programs that reduce the effects of on-going land-use practices on the environment. A major portion of their effort is to advise residents on the management of soil, water, soil amendments and other resources used for agriculture and home gardening. RCDs are supported by state and local grants. They provide leadership in partnership efforts to help people conserve, maintain, and improve our natural resources and environment. Programs include Emergency Watershed Protection, Environmental Quality Incentives, Resource Conservation and Development, Soil Survey Programs, Soil and Water Conservation Assistance, Watershed Protection, River Basin, and Flood Operations, Wetlands Reserve and Wildlife Habitat Incentives. They do not enforce regulations but instead serve the interests of local residents and businesses. To find out more, visit http://www.mdrcd.ca.gov/current.html.

San Bernardino Mountains Land Trust: SBMLT grew out of heightened conservation concerns in the early 1990s, when the San Bernardino National Forest faced multiple threats to its ecological integrity. This group has been involved in several successful land acquisition efforts for conservation. SBMLT has an advisory committee that assists in several areas of expertise, including legal, real estate, forestry, biology, journalism, and publications. Land trusts are critical to implementing the Linkage Design, and the SBMLT is working diligently to keep the forest intact. For more information, see http://www.lta.org/findlandtrust/CA.htm.

San Bernardino Valley Audubon: Audubon members are dedicated to protecting birds, wildlife, and our shared environment. They work with policymakers in Washington, D.C., state legislatures, and local governments across the country to restore and protect our natural legacy, secure funds for vital conservation programs, and preserve key natural areas. The San Bernardino Valley Audubon Chapter has over 1600 members in San Bernardino and Riverside Counties and is actively engaged in conservation activities in this region. For more information, go to www.sbvas.org.

Santa Monica Mountains Conservancy: This state agency was created by the Legislature in 1979 and is charged with the primary responsibility for acquiring land with statewide and regional significance. Through direct action, alliances, partnerships, and joint powers authorities, the Conservancy's mission is to strategically preserve, protect, restore, and enhance treasured pieces of Southern California's natural heritage to form an interlinking system of parks, open space, trails, and wildlife habitats that are easily accessible to the general public. The SMMC is a partner in the South Coast Missing Linkages effort. For more information on SMMC, visit them at http://www.smmc.ca.gov.

Save our Forest Association, Inc.: The Save Our Forest Association, Inc. (SOFA) was formed to stop inappropriate land exchanges within the San Bernardino National Forest, though now they work on a variety of other critical conservation issues. SOFA monitors and comments on any large development projects which affect the long term health and vitality of the forest ecosystem in the San Bernardino Mountains, including large subdivisions, water extraction, etc. They also closely monitor commercial logging, cattle grazing, and off-road vehicle use. To find out more about the association, visit their website at www.saveourforestassoc.org.

Sierra Club's Southern California Forests Campaign: Sierra Club volunteers and staff have created the Southern California Forests Campaign to encourage public involvement in the 4 southern California Forest's Resource Management Plan revision process. The goals of the campaign are to reduce the threats to our forests and to enjoy, protect and restore them. For more information on the Sierra Club's campaigns, go to http://www.sierraclub.org.

South Coast Wildlands: South Coast Wildlands is a non-profit group established to create a protected network of wildlands throughout the South Coast Ecoregion and is the key administrator and coordinator of the South Coast Missing Linkages Project. For all 15 priority linkages in the Ecoregion, South Coast Wildlands supports and enhances existing efforts by providing information on regional linkages critical to achieving the conservation goals of each planning effort. For more information on SCW, visit their website at http://www.scwildlands.org.

South Coast Missing Linkages Project: SCML is a coalition of agencies, organizations and universities committed to conserving 15 priority landscape linkages in the South Coast Ecoregion. The project is administered and coordinated by South Coast Wildlands. Partners in the South Coast Missing Linkages Project include but are not limited to The Wildlands Conservancy, The Resources Agency California Legacy Project, California State Parks, California State Parks Foundation, United States Forest Service, National Park Service, Santa Monica Mountains Conservancy, Conservation Biology Institute, San Diego State University Field Station Programs, The Nature Conservancy, Environment Now, and the Zoological Society of San Diego's Conservation and Research for Endangered Species. For more information on this ambitious regional effort, go to http://www.scwildlands.org.

The Nature Conservancy: TNC preserves the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. TNC is a partner in the South Coast Missing Linkage Project. For more information on their activities, go to http://www.tnc.org.

The Summertree Institute: Plants of the arid southwest survive conditions that commonly defeat other life forms. In order to help the rapidly developing communities of the southwest recognize and retain their long-lived native plants, The SummerTree Institute has launched SAVING THE ANCIENTS campaign. This community awareness program is currently focused on the native plants of the Mojave and Colorado Deserts, and is designed to encourage protection and planting of long-lived southwest native plants, while improving the environment for people and wildlife. For more information on the Institute, go to http://www.summertree.org.

The Wildlands Conservancy: The Wildlands Conservancy is a non-profit, member-supported organization dedicated to land and river preservation, trail development and environmental stewardship through education. Their Save the Saints Program brings together multiple land trusts and conservancies to identify key lands for acquisition within National Forest boundaries and lands contiguous with the Forests in the Santa Ana, San Gabriel, San Jacinto, and San Bernardino Mountains. TWC has acquired thousands of acres in the Mohave Desert and owns and manages Pipes Canyon, Mission Creek, and Oak Glen Preserves in the San Bernardino Mountains. TWC is a vital partner in the South Coast Missing Linkages project. For more information, please visit their website at http://www.wildlandsconservancy.org.

US Fish and Wildlife Service: The U.S. Fish and Wildlife Service works to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The agency can provide support for prosecuting violations to the Endangered Species Act, law enforcement, permits, and funding for research on threatened and endangered species. The federal Endangered Species Act as amended (16 U.S.C. 1534) authorizes USFWS to acquire lands and waters for the conservation of fish, wildlife, or plants with Land and Water Fund Act appropriations. The added protection provided by the Endangered Species Act may also be helpful for protecting habitat in the linkage from federal projects. For more information, visit their website at http://www.fws.gov.

US Fish and Wildlife Service Partners for Fish and Wildlife Program This program supplies funds and technical assistance to landowners who want to restore and enhance wetlands, native grasslands, and other declining habitats, to benefit threatened and endangered species, migratory birds, and other wildlife. This program may be helpful in restoring habitat on private lands in the Linkage Design. For more information on this program, please go to http://partners.fws.gov.

US Forest Service: The mission of the USDA Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. The four southern California Forests (Los Padres, Angeles, San Bernardino, and Cleveland) have recently finalized their Resource Management Plans. The Final Environmental Impact Statement and Forest Plans have identified connecting the four forests to the existing network of protected lands in the region as one of the key conservation strategies for protecting biodiversity on the forests. The USFS is allocated Land and Water Conservation Funds annually, which are designed to protect recreational open space, watershed integrity, and wildlife habitat and may be a source of funds for protecting land in the planning area. The Forest Service is taking a proactive role in habitat connectivity planning in the region as a key partner in the South Coast Missing Linkages Project. For more information, go to http://www.fs.fed.us/r5/scfpr.

US Geological Survey, Biological Resources Division: The Biological Resource Division (BRD) works with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources. BRD develops scientific and statistically reliable methods and protocols to assess the status and trends of the Nation's biological resources. BRD utilizes tools from the biological, physical, and social sciences to understand the causes of biological and ecological trends and to predict the ecological consequences of management practices. BRD enters into partnerships with scientific collaborators to produce high-quality scientific information and partnerships with the users of scientific information to ensure this information's relevance and application to real problems. For more information, go to http://www.biology.usgs.gov.

West Mojave Plan- A Habitat Conservation Plan and California Desert Conservation Area Plan Amendment: BLM describes the West Mojave Plan as "an attempt at defining a regional strategy for conserving plant and animal species and their habitats and to define an efficient, equitable, and cost-effective process for complying with threatened and endangered species laws." The Plan includes a Federal component that will amend the existing 1980 California Desert Conservation Area Plan, and a Habitat Conservation Plan (HCP) that will cover development on private lands. The BLM and 27 other federal and state agencies, cities and counties participated in this planning process to address the conservation of the desert tortoise and several other species status plant and wildlife species. To find out more about this planning effort, visit www.ca.blm.gov/cdd/wemo.html.

Wildlife Conservation Board: The Wildlife Conservation Board administers capital outlay for wildlife conservation and related public recreation for the State of California. The Wildlife Conservation Board, while a part of the California Department of Fish and Game, is a separate and independent Board with authority and funding to carry out an acquisition and development program for wildlife conservation. For more information on WCB, go to http://www.dfg.ca.gov/wcb.

Zoological Society of San Diego: The Applied Conservation Division of the Society's research department (Conservation and Research for Endangered Species) is working to conserve natural habitats and species in southern California, as well as other parts of the world. For example, the Applied Conservation Division supports conservation of southern California ecosystems through seed banking of endangered plant species, and ongoing studies of local birds, reptiles, and mammals and their habitats. For more information on ZSSD, go to http://www.sandiegozoo.org.

A Scientifically Sound Plan for Conservation Action

Humans are significant agents of biogeographic change in southern California by converting native habitats to urban and agricultural uses and altering the movements of organisms, nutrients, and water through the ecosystem. The resulting fragmentation of natural landscapes threatens to impede the natural processes that support one of the world's greatest warehouses of species diversity.

This interaction between human development and biodiversity is one of the great and potentially tragic experiments of our time. It creates a unique challenge for land managers and conservation planning efforts – to mitigate massive changes to once intact ecosystems. The conservation plan for the San Bernardino-Granite Mountains Linkage addresses these challenges by seeking to influence regional patterns of development in a manner that best preserves natural landscape-level processes in the region.

The prioritization of this linkage for conservation, and the demarcation of lands requiring protection within the linkage, are based on the best available conservation techniques and the expertise of biologists working in the region. This project provides a strong biological foundation and a quantifiable, repeatable, conservation design approach that can inform successful conservation action.

Next Steps

The San Bernardino to Granite Mountains Linkage Design is a scientifically sound starting point for conservation implementation and evaluation. This plan can be used as a resource by regional land managers to assist them in their critical role in sustaining biodiversity and ecosystem processes. Existing conservation investments in the region are already extensive, including lands managed by the US Forest Service, Bureau of Land Management, California Department of Fish and Game, and the State Lands Commission. Each public property within existing protected core areas as well as the linkage itself serves a unique role in preserving some aspect of the connection. Incorporating relevant aspects of this plan into individual land management plans provides an opportunity to jointly implement a regional conservation strategy.

Additional conservation action will also be needed to address transportation barriers. Recommended tools include road renovation, construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, acquisition, and others. These recommendations are not exhaustive, but are meant to serve as a starting point for agencies, organizations, and individuals interested in preserving and restoring linkage function. We urge the reader to keep sight of the primary goal of conserving landscape linkages -- to promote movement between targeted core areas over broad spatial and temporal scales -- and to work within this framework to develop a wide variety of restoration options for maintaining and improving linkage function. To this end, we provided a list of organizations, agencies, and regional projects that provide opportunities for collaborative implementation.

Public education and outreach is vital to the success of this effort – both to change land-use activities that threaten species existence and movement in the linkage and to generate support for the conservation effort. Public education can encourage recreational users and residents at the urban-wildland interface to become active stewards of the land and to generate a sense of place and ownership for local habitats and processes. Such voluntary cooperation is essential to preserving linkage function. The biological information, figures, and tables in this plan are ready materials for interpretive programs. We have also prepared a 3D animation (Appendix C on the enclosed CD) that provides a landscape perspective of the linkage.

Successful conservation efforts are reiterative, incorporating and encouraging the collection of new biological information that can increase understanding of linkage function. We strongly support the development of a monitoring and research program to address the habitat needs of species in the Linkage Design area and their movements (of individuals and genes). The suite of predictions generated by the GIS analyses conducted in this planning effort represent hypotheses to be tested and refined by long-term monitoring programs.

The remaining wildlands in southern California form a patchwork of natural open space within one of the world's largest metropolitan areas. Without further action, our existing protected lands will become isolated in a matrix of urban and industrial development. Ultimately the fate of the plants and animals living on these lands will be determined by the size and distribution of protected lands and surrounding development and human activities. With this linkage conservation plan, the outcome of land use changes can be altered to ensure the greatest protection for our precious natural areas at the least cost to our human endeavors. We envision a future interconnected system of natural space where our native biodiversity can thrive.

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Appendices

South Coast Missing Linkages Project: Habitat Connectivity Workshop August 7, 2002

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South Coast Missing Linkages Workshop
Wednesday August 7, 2002 at the University of Redlands

8:30	*Welcome Address* Geary Hund, California State Parks
8:40	*Where Linkage Planning and MSCPs Meet* Tom Scott, University of California Riverside
9:00	*Connectivity Planning for Plants* Tim Krantz, University of Redlands
9:20	*The Role of Arthropods in Wildlife Linkages* Greg Ballmer, Tri-County Conservation League
9:40	*Reptiles and Amphibians in the Transition and Foothill Regions of the San Bernardino Mountains* Chris Brown, U.S. Geological Survey Biological Resources Division
10:00	Break
10:15	*Ornithological Considerations for Habitat Connectivity Planning* Chet McGaugh & John Green, AMEC
10:35	*Distribution, Biology, Dispersal, and Habitat Connectivity Issues Affecting the Spotted Owl in Southern California* William S. La Haye, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul
10:55	*Considering Small Mammals in Linkage Planning for the South Coast Ecoregion* Wayne Spencer, Conservation Biology Institute
11:15	*Cougars, Corridors, and Conservation* Paul Beier, Northern Arizona University
11:45	*Considerations for Connectivity & Overview of Working Groups* Claudia Luke, San Diego State University Field Station Programs
12:10	Lunch – *Vouchers will be issued to all participants for use in the Commons*
1:00	Working Group Session

<u>Taxonomic Group Leaders</u>

Plants:	Tim Krantz
Invertebrates:	Gordon Pratt
Herps/Fish:	Chris Brown & Claudia Luke
Birds:	Bill La Haye
Mammals:	Paul Beier

4:45 *Closing Remarks* by Kristeen Penrod, South Coast Wildlands Project

5:00 Adjourn; Please join us for a Beer & Wine Social

Workshop Summary

Geary Hund, California State Parks – *Welcome*

- Missing Linkages initiative identified 232 statewide linkages; 69 are associated with the South Coast Ecoregion; 15 most crucial are focus of collaborative planning effort coordinated by South Coast Wildlands Project; this workshop will lay the biological foundation for corridor planning between the San Bernardino Mountains and surrounding ranges (San Gabriel, Granite, Little San Bernardino, and San Jacinto Mountains)
- Preservation of biodiversity in southern California will require connectivity
- Linkage between Santa Ana Mountains and Chino Hills was established across 91 freeway at Coal Canyon, where mountain lion established home range on both sides of freeway as documented by Paul Beier; private properties purchased and protected, and CalTrans will close the exit, remove pavement, and restore the underpass
- California Floristic Province is one of 25 global biodiversity hotspots; South Coast Ecoregion is considered a "hotspot within a hotspot" deserving special attention
- Scientific investigation combined with environmental advocacy can achieve landscape-level connectivity needed for nature to adapt to changes over time

Tom Scott, University of California, Riverside - *Where Linkage Planning and MSCPs Meet*

Summary: The focus of my current research is examining biologically diverse hot spots within the Riverside and Coachella Valley Multiple Species Conservation Plans (MSCPs). Some of the linkage areas we will be considering today are located within these MSCPs. My discussion will highlight some of the diverse species that occur in these linkage areas, and some considerations for habitat corridor planning in areas with high biological diversity.

Biography: Dr. Scott is an Adjunct Associate Professor in the Department of Earth Sciences at the University of California, Riverside. He received his PhD at the University of California in 1987. His research focuses on wildlife conservation in fragmented and altered landscapes, including studies of wildlife movement, habitat use, and population biology in oak woodland, sage scrub, and riparian habitats; behavioral changes and adjustments in habitat use of woodland bird species in response to human activities; the conservation and management of island bird species through captive propagation, predator control, and habitat restoration.

- Political mentality against southern California exists due to intense level of development and high representation in Congress; this is land of geologic, climatic, and human superlatives; regional single family housing is worth up to $27 billion per year
- Landscape disturbance began in 1940s with water availability; urban sprawl/suburbia expansion occurring in developed areas around the world; educated, politically active individuals living in Wildland-Urban Interface (WUI); can achieve conservation with local support (residents dislike rapid landscape change); about 38-48% of landscape will be converted; 100 km WUI edge in San Diego County, 2300 km in Riverside County

- One acre of natural habitat in southern California more valuable for global biodiversity preservation than acre of lowland tropical rainforest; tropics are diverse, but southern California's high level of endemism reveals unique suite of species at each location
- California contains 30% of entire country's endemic taxa, and has semitropical influence; endemics have narrow distributions due to range contraction or isolation
- Multiple edges of distributions (species margins) meet in southern California, which has resulted in abundance of endemic species
- High level of endemism at Baldwin Lake/ Pebble Plains, Otay Mesa, Del Mar, Vail Lake, Sierra Madre/Occidental; geologic calliope ranges from "brand new" to 9 million years old, with mountains still rising (11,000 feet but less than 2 million years old) as Pacific and North American Plates slide past each other; San Jacinto Peak is greatest vertical climb in North America (800 to 3200 m over less than seven km); incredible spatial diversity, but landscape variation is a challenge for functional linkage planning
- Multiple Species Conservation Plans (MSCPs) direct land use and resource management planning; Riverside County and Western Mojave plans are being developed, and include habitat linkages between preserves; important for biologists to get involved in MSCP process, the political solution to Endangered Species Act issues; even with plans, landscape will suffer from air pollution, recreational use, and urban drool (excess runoff often supporting harmful exotic species, such as bullfrogs)
- Linkages must be functional, with stated goals and measurable benefits

Tim Krantz, University of Redlands – *Connecting Rare Plant Communities*

Summary: People don't think of plants as migrating, but they certainly do—not as individuals, but over the span of generations. Montane plant communities migrate up and down in elevation over time between glacial and interglacial episodes, while valley species move through passes and along flood plains. Most of Southern California's rare plant communities are characterized by restricted suitable habitats and/or limited dispersal capability. Compounding those natural limitations, habitat fragmentation, flood control measures, invasive exotic species and other developments constrain the remaining opportunities to provide connections between rare plant populations and communities.

Biography: Dr. Krantz is an Assistant Professor of Environmental Studies at the University of Redlands; and is Director of the Salton Sea Database Program. He is a recognized authority on the flora of the San Bernardino, San Gabriel and San Jacinto Mountains and has worked extensively on endemic plants and plant communities of the region. He has worked for many years, first as an employee and later as a consultant to the Southern California National Forests, mapping endemic plant distributions; and served for six years on the San Bernardino County Planning Commission.

- Rare plant communities move over long-term (hundreds to thousands of years) between glacial and interglacial episodes (fossil evidence of conifer species found in Santa Ana and San Jacinto washes); usually restricted to specific ecological conditions; poor dispersal abilities, as movement away from favorable habitat would be disadvantageous
- Linkages contain montane communities (San Bernardino, San Gabriel, San Jacinto) separated by barriers/corridors (Cajon Wash, Banning Pass and Santa Ana River)
- Big Bear region has extremely diverse endemic flora; plant communities include pebble plains (relic from ice age) as "islands in a sea of conifers" restricted to dense clay soils; mapped using indicator species (Bear Valley sandwort and Kennedy's

buckwheat, an alpine plant found at 7000 ft – nearest relatives located at nearby 11,500 ft summit)

- Sub-alpine meadow: clay soil with more water; associated with several endangered plants (Big Bear checkerbloom, slender-petal mustard, California dandelion)
- Mapped extant locations of plant communities, forming network of preserves to protect best remnants of these unique communities; corridors over long-term provide genetic resources for plant communities to make necessary connections
- Another community restricted to carbonate resources/limestone soils (includes cushion berry buckwheat and Parish's daisy); nearest relatives in desert communities; concentrations of endemic species threatened by limestone mining, but less than 30% of mineral resource actually valuable for mining – great opportunity for conservation
- Linkage areas also contain southern rubber boa, spotted owl, bald eagle, unarmored three-spine stickleback, Andrew's marble butterfly; plant communities are animal communities, and so habitat connectivity will benefit both flora and fauna
- Lowland passes/washes may act as barriers for montane species
- San Jacinto slender-horned spineflower and Santa Ana River woolly star are restricted to alluvial fan sage scrub, found between mountain ranges
- Seven Oaks Dam on upper Santa Ana River currently prevents natural flood scour events that maintain dynamic ecosystem; sand/gravel mining, flood control and development are fragmenting community
- Shortest route not necessarily best route; easier for most species to cross fewer life zones between mountain ranges (San Timoteo Canyon, Wildwood Canyon, and Crafton Hills may link San Jacinto and San Bernardino Mountains better than Banning Pass)

Greg Ballmer, Tri-County Conservation League - *The Role of Arthropods in Wildlife Linkages*

Summary: Arthropods are ubiquitous in all habitats and are largely responsible for maintaining habitat quality and productivity. For arthropods, habitat fragmentation frequently leads to speciation rather than extinction. Most arthropods, by virtue of their small size, ecological specialization, high reproductive rate, and small home ranges, do not benefit directly from habitat linkages. Exceptions include arthropod species having a metapopulation structure. Also, arthropod communities benefit indirectly from habitat linkages when those linkages help to maintain populations of vertebrates, whose presence is critical to maintaining overall community structure.

Biography: Greg Ballmer earned a B.S. degree in Entomology at UCR in 1967, he then spent three years in Thailand as a Peace Corps Volunteer entomologist in the Thai National Malaria Eradication Project. Greg returned to UCR in 1971, where he completed his M.S. degree in Entomology in 1973. Currently, Greg lives in Riverside and works as a Staff Research Associate in the Entomology Department at University of California, Riverside. Although his professional experience is primarily with agricultural pest control, Greg's private interests include butterfly biology and systematics, arthropod habitat conservation, and overall preservation of native California habitats and biotic communities. In 1989 Greg Ballmer petitioned the US Fish and Wildlife Service to list *Rhaphiomidas terminatus abdominalis* (Delhi Sands Flower-loving Fly) as an Endangered Species; it received that status in 1993.

- Invertebrates are primary intermediate between plant and animal biomass, and provide vital ecosystem services (food for invertebrates and small vertebrates, breakdown of organic wastes/nutrient recycling, soil aeration, pollination, vector for seed dispersal)
- Habitat is combination of biotic and abiotic factors with which an organism interacts to support its growth and reproduction; organism is integral part of its habitat
- Linkages allow long-term gene flow which increases functional genetic diversity of population; this helps overcome stochastic events and long-term environmental changes
- Linkages allow short-term movement to escape catastrophic events, use accessory habitat and re-colonize after disturbance; arthropods occupy diversity of habitats and community types at different points in life cycles, and therefore need connectivity
- Arthropods maintain habitat quality within linkage areas; habitat loss or conversion can form serious barrier to insect movement; must link small invertebrate populations to maintain gene pool and metapopulation structure
- Certain arthropods may not need linkages (those that have high reproductive rate, occupy restricted or widely spaced geographic areas, are highly migratory or wind dispersed); rapid evolution/speciation can occur when populations are isolated
- Vernal blue butterfly subspecies – in southern California only occurs on somewhat barren ridgetop in San Bernardino Mountains with specific buckwheat host plant – linkages will not benefit such Pleistocene relics with spotty distribution – not found in nearby appropriate locations that contain the host plant
- Migratory painted lady butterfly has ephemeral populations and does not need linkages
- Delhi Sands flower-loving fly, an endemic arthropod threatened by habitat fragmentation, inhabits scattered sand patches; endemic Jerusalem cricket also utilizes sandy habitat; both are capable of re-colonizing habitat from source population after disturbance

Chris Brown, USGS Biological Resources Division - *Reptiles and Amphibians in the Transition and Foothill Regions of the San Bernardino Mountains*

Summary: The transition and foothill regions of the San Bernardino Mountains are biological hotspots in San Bernardino County, having a unique mixture of coastal, mountain and desert herpetofauna. These areas are also important connections between the Transverse Ranges. Although much of this habitat still exists, development is encroaching on the San Bernardino Mountains, weakening these linkages, and several barriers already exist in a setting that was historically wide open. We have been studying the herpetofauna of the transverse ranges since 1995 in order to better understand the distribution and needs of the sensitive reptiles and amphibians throughout this region. Successful management of the diverse herpetofauna within these historical corridors of the Transverse Ranges must take into consideration the heterogeneous and expansive nature of the transition zones and foothills that connect the San Bernardino Mountains with outlying ranges.

Biography: Chris Brown is a biologist for the US Geological Survey, Western Ecological Research Center. Since 1995, he has been studying the herpetofauna of southern California to support research needs of UC San Diego, San Diego State University, National Biological Survey and the USGS. His interests in herpetology have focused on distribution, status and natural history of the mountain and coastal herpetofauna of southern and Baja California.

- Linkage area contains wide range of habitats; linkages from San Bernardino Mountains to surrounding ranges include coastal and desert influences, transitional belt of habitat around mountains, and montane habitats, resulting in phenomenal diversity; working group must select multiple species to represent the four different linkages - horned lizard, speckled rattlesnake, and western spadefoot toad recommended as focal species
- 1 turtle, 13 lizards, 19 snakes, 4 salamanders, and 7 frogs and toads inhabit planning area; (SB = San Bernardino Mountains, SG = San Gabriel Mountains, SJ = San Jacinto Mountains, LSB = Little San Bernardino Mountains, GM = Granite Mountains)
- Salamanders demonstrate limited connectivity between these mountain ranges; garden slender salamander (south-facing coastal slopes; SB – SG, SJ); San Gabriel Mountain slender salamander (SB – SG); large blotch salamander (SB – SJ); Monterrey ensantina best example for species movement (gene flow) between all these ranges
- Frogs and toads: western toad (SB – SG, LSB); arroyo toad (SB – SG, SJ); red spotted toad (desert slopes); spadefoot toad (little known about distribution, but recently found in foothill transition zones around SB – SG, SJ); California treefrog (fairly common in all ranges); mountain yellow-legged frog (most historical habitat lost in Santa Ana wash)
- Desert tortoise on desert slopes (SB – GM, SJ); tortoises reside within linkage areas
- Fish: speckled dace (SB – SG), found in Cajon wash and Lytle Creek, but rather isolated
- Lizards: zebra-tailed lizard (SB - SJ); coast horned lizard (SB – SJ, SG, LSB); long-nosed leopard lizard (desert transition zone; SB – SJ, SG, LSB); Gilbert skink (possibly SB – GM); western whiptail (all ranges; species variety may be result of isolation)
- Snakes: glossy snake (resides within linkage areas; SB – GM, recommended focal species); ringneck snake (SB – SG); distribution largely unknown for: red racer, patch-nosed snake, lyre snake, and rosy boa (which does not like to cross even dirt roads); southwestern speckled rattlesnake (easily detectable, found throughout linkage areas, recommended as focal species, good barometer for snake movement)
- Amphibian visual encounter surveys; targeted species for San Bernardino area include arroyo toad, western toad, California treefrog, Pacific treefrog, spadefoot toad; field biologists noting movement barriers (roads and dams), impacts of recreation (ATV use and illegal dumping), development impacts (light pollution, habitat and connectivity loss)
- Herpetofauna biodiversity data (starting in 1999): pitfall trap arrays at 51 study sites throughout southern California; over 630 arrays (4400 buckets, 1800 snake traps, 28 km fencing); captured 46 species in 18 families; study sites have between 9-33 species
- Historical perspective must consider natural history of desert and coastal species, as different forms intergrade (ex – gopher snakes at Silverwood Lake); natural gene flow should be conserved; 5 different forms of red racer in California

Chet McGaugh & John Green, AMEC – *Ornithological Considerations for Habitat Connectivity*

Summary: The power of flight, and the amazing dispersal and migratory abilities of birds enable them to traverse huge expanses of unsuitable habitat. Habitat connectivity at the landscape level is not an issue for most birds. Birds resident within the linkages, or living in similar habitats adjacent to the linkages, would benefit most from the connectivity of large habitat patches. Sensitive species and ecological specialists would benefit more from conservation measures within their various habitats than from an attempt to establish linkages.

Biography: Chet McGaugh is a wildlife biologist specializing in ornithological studies. As a consultant (currently with AMEC Earth and Environmental in Riverside) and as an avid birdwatcher, he has studied the distribution and ecology of birds in this ecoregion for 25 years. He participated in the U.S. Fish and Wildlife Service's life history study of the California Gnatcatcher, and has conducted hundreds of surveys for sensitive bird species, including the Least Bell's Vireo, Southwestern Willow Flycatcher, and the California Gnatcatcher. He is the compiler of the Salton Sea – North Christmas Bird Count.

Biography: John Green is a wildlife biologist specializing in ornithological studies. As a consultant with AMEC Earth and Environmental, John specializes in the monitoring of sensitive bird populations such as the Least Bell's Vireo. John's many contributions to the ornithological community in this ecoregion include his acclaimed Southeastern California Rare Bird Alert, which is the Internet clearing-house for bird sightings in the region, and his participation in a valley-wide survey of Mountain Plovers in the Imperial Valley in 2002.

- Many bird species are capable of easily dispersing between suitable habitats
- Flightless birds and those that can only fly limited distances need connectivity; California gnatcatcher is weak flyer with poor dispersal over unsuitable habitat, and therefore is susceptible to impacts from habitat fragmentation
- Diversity in flying ability and movement patterns between species
- No need to consider water birds or migratory species for connectivity planning
- Sedentary birds and birds unlikely or unwilling to disperse over large areas of unsuitable habitat will benefit from linkages; ex – cactus wren, rock wren, scrub jay, California thrasher, wrentit, Bewick's wren, bushtit; gene flow occurs if populations are not isolated; many birds would utilize habitat available within linkage areas, but montane species have characteristics and habitat needs distinct from birds inhabiting most of the lower elevation linkage areas; unknown whether many mountain species cross washes and desert habitat to move between the ranges
- Acorn woodpecker shows seasonal movements to hospitable resource areas
- Band-tailed pigeon probably crosses between ranges, which allows gene flow
- Sensitive species that would utilize linkages include Le Conte's thrasher, sage sparrow, rufous-crowned sparrow, burrowing owl, and loggerhead shrike

Bill LaHaye, University of Minnesota, St. Paul – *Distribution, Biology, Dispersal, and habitat connectivity issues affecting the Spotted Owl in southern California.*

Summary: The Spotted Owl is a large avian predator that primarily inhabits older forests in western North America. This owl is an interior forest species whose flight adaptations have been driven by the need for maneuverability in densely wooded environments. Thus in spite of having a wingspan exceeding one meter, the Spotted Owl is a weak flyer in open terrain. This may restrict the dispersal of this owl in regions lacking contiguous forest. Here I present the pertinent results of a 12-year demographic study on this species in the San Bernardino Mountains. Information will be presented on general biology, current and historic distribution, dispersal, and metapopulation aspects of the Spotted Owl in southern California.

Biography: Bill LaHaye received a Master of Science degree from Humboldt State University in 1989 and has been studying the Spotted Owl for 20 years. While he has worked on various projects studying this species in California, Arizona and New Mexico, the majority of Bill's efforts have been in southern California. The topics of Bill's published works include natural history, diet, demography, dispersal, and metapopulation dynamics.

- Spotted owl demography research conducted in San Bernardino Mountains; owls inhabit interior forests with dense canopy and ambush prey; live in continuous forest at higher elevations, with distribution more patchy and linear at lower elevations; may have historically utilized oak woodlands; current distribution in southern California includes islands of mountaintop habitat with metapopulation becoming fragmented
- Owls studied for 12 years in San Bernardino Mountains and 6 years in San Jacinto Mountains; over 95% of encountered owls were banded; no movement between mountain ranges has been documented during this study
- About 850 owls banded in San Bernardino Mountains (over 300 adults and over 500 juveniles); researchers were surprised that no juvenile dispersal was observed

Wayne Spencer, Conservation Biology Institute - *Considering Small Mammals in Linkage Planning for the South Coast Ecoregion*

Summary: For good reasons, linkage planning between major mountain ranges tends to focus on large, wide-ranging mammals. Smaller mammals should not be ignored in these efforts, however, because they can play numerous important roles in maintaining or monitoring linkage functionality. For example, small mammals are essential prey for larger carnivores within landscape linkages, may represent ecological "keystone species," and may be useful indicators for monitoring effects of fragmentation. Small mammals could be classified by their irreplaceability and vulnerability in assessing which may be useful indicators of linkage function, or they could be classified by their major habitat associations or ecological functions. Although a few small mammals may use inter-montane linkages to disperse from one mountain range to another, those species living completely within linkages at lower elevations may be even more important for assessing inter-montane linkages. Linkage planning should therefore consider "orthogonal linkages," or those that follow elevational bands or drainages crossed by inter-montane linkages. For example, such rare rodents as the San Bernardino Kangaroo Rat and Palm Springs Pocket Mouse inhabit desert washes and alluvial fans that lie between adjoining montane habitats. Landscape linkages should therefore be planned to capture essential habitat for these species across their breadth while connecting between mountains on either side. Other general guidelines concerning small mammals in linkage planning include: (1) provide live-in habitat for prey species; (2) provide for natural processes like fire and erosional-depositional forces that replenish habitats; (3) provide for the full range of ecological gradients across the linkage, such as the full range of geologically sorted substrates in alluvial fans; (4) provide for upslope ecological migration in response to climate change; and (5) consider the limited dispersal tendencies of small mammals relative to dispersal barriers, such as roads and canals, and avoid creating death traps for them when designing crossings for larger species. Linkage planning should also consider ways to provide niches for habitat specialists, such as creating bat roosts in bridges or overpasses designed to accommodate wildlife movement.

Biography: Dr. Spencer is a wildlife conservation biologist who specializes in applying sound ecological science to conservation planning efforts. He has conducted numerous field studies on sensitive wildlife species, with a primary focus on rare mammals of the western U.S. Dr. Spencer has studied martens, fishers, and other carnivores in forest and taiga ecosystems, as well as rare rodent species and communities in the southwestern U.S. In the South Coast Ecoregion he has served as principal investigator for research designed to help recover the critically endangered Pacific Pocket Mouse and has worked intensively on efforts to conserve endangered Stephens' Kangaroo Rats, among other species. Dr. Spencer is currently serving as Editor in Chief for a book on mammals of San Diego County. He also serves as a scientific advisor on a variety of large-scale conservation planning efforts in California, including the San Diego MSCP/MHCP, and the eastern Merced County NCCP/HCP. He is increasingly being asked by state and federal wildlife agencies to help facilitate scientific input in conservation planning efforts, and to help train others in science-based conservation planning.

- Most linkages designed for large mammals that must move between large habitat areas to survive and reproduce; many smaller species will not use inter-montane linkages for movement, but rather will benefit from the protected habitat
- Small mammals (especially rodents and lagomorphs) are prey for larger mammals; small mammals are more dispersal limited and habitat specialized than larger mammals
- Keystone species include burrowing rodents (pocket gophers, ground squirrels and kangaroo rats) that modify soil, impact plant distribution, create habitat for other species
- Micro-habitat specialists; pocket mouse subspecies adapted to slices of vegetation community or geological substrate; genetic differentiation due to geographic isolation
- Conservation planning recognizes irreplaceability and vulnerability (incorporating and connecting habitat for rare endemic species with limited distributions)
- For most taxa (including small mammals), linkages are not designed to move individuals of various species from one mountain range to another (many have not moved between ranges for tens of thousands of years), but rather to provide for long-term genetic exchange and adaptation; species will benefit from preserved habitat in linkages
- Orthogonal linkage concept: for small mammals distributed in elevational bands in particular vegetation communities or soil strata, breadth of linkage is important; habitat located at right angle to general linkage arrows; connect both across and along linkages
- Inhabitants of pinyon juniper, oak woodland, chaparral, and other lower elevation areas of linkages may be planned for (western gray squirrel, dusky-footed woodrat, chipmunk)
- Different suite of species needed for each linkage; species that should be considered for planning: round-tailed ground squirrel, Mojave ground squirrel, western gray squirrel, chipmunk, San Bernardino kangaroo rat, little pocket mouse, long-tailed weasel, spotted skunk, ringtail, badger (fragmentation-affected grassland species), kit fox, dusky-footed woodrat, pinyon mouse, pocket gopher (keystone burrowing species, dispersal limited)
- Plans for bat roosting structures can be incorporated into bridge and overpass structures
- Linkages for large mammals must provide habitat for prey base (unless function is simply to move species across and away from roads); also, consider location of rare and endemic species to compliment linkage design
- With climate change, expect upslope migration resulting from global warming; linkages should be broad enough to accommodate natural processes (flood scour and deposition, fire); capture whole environmental gradients to protect multiple specialized species

Paul Beier, Northern Arizona University – *Cougars, Corridors, and Conservation*

Summary: Because the puma or cougar lives at low density and requires large habitat areas, it is an appropriate umbrella species for landscape connectivity in the South Coast Ecoregion. A crucial issue, however, is whether connectivity is provided by narrow corridors through urban areas (an artificial substitute for natural landscape connectivity). In particular, corridors decrease extinction risk only if they facilitate dispersal of juveniles between mountain ranges. To address this issue, we conducted fieldwork on pumas in the Santa Ana Mountain Range, a landscape containing 3 corridors (1.5, 6, and 8 km long). Each of the 3 corridors was used by 2 or more dispersing juvenile puma. Five of 9 radio-tagged dispersers successfully found and used a corridor. The corridors in this landscape were relict strips of habitat, not designed to facilitate animal movement. Puma doubtless would be even more likely to use well-designed linkages. Puma will use corridors that lie along natural travel routes, have < 1 dwelling unit per 50 acres, have ample woody cover, lack artificial outdoor lighting, and include an overpass or underpass integrated with roadside fencing at high-speed road crossings. "If we build it, they will come."

Biography: Paul Beier is Professor of Conservation Biology and Wildlife Ecology at Northern Arizona University. He has worked on how landscape pattern affects puma, northern goshawk, Mexican spotted owls, white-tailed deer, and passerine birds (the latter in both West Africa and northern Arizona). He serves on the Board of Governors for the Society for Conservation Biology. A full description of his activities is available at http://www.for.nau.edu/~pb1.

- Pumas exist at low density; functional connectivity needed for movement and dispersal
- Santa Ana Mountains study: 9 radio-collared juvenile dispersers tracked; three corridors/habitat constrictions present, but not designed for habitat connectivity:
  1. Coal Canyon (short freeway undercrossing near railroad tracks, stables, and golf course); 3 lions attempted to cross (2 successful); M6 was premier user of corridor, crossing under freeway more than 22 times in 18 months; home range included habitat on both sides of freeway; after completion of study, surrounding properties were preserved, and CalTrans agreed to close underpass to traffic, remove asphalt, and turn over to California State Parks for restoration and use as wildlife linkage
  2. Santa Ana – Palomar (longer, I15 is major impediment, patchwork of land ownership); 2 lions attempted to cross (1 successful); one lion crossed Santa Ana – Palomar linkage by walking across I15 rather than finding a safer route underneath; point of crossing was just north of border patrol/INS checkpoint; several lions were killed crossing at this same site – multiple lions are demonstrating preferred crossing site, which should be focus of planning for vegetated freeway overpass
  3. Arroyo Trabuco (protected from urban areas by tall bluffs, contains dense riparian vegetation, resident deer population, darkness, water); 3 lions attempted to cross (3 successful); comfortable corridor – lions spent 2-7 days traveling through corridor
- 5 of 9 study animals found and successfully used one of the three corridors; sites were not designed for animal movement, which explains unsuccessful attempts
- Photographic overview of potential linkage areas from field reconnaissance to demonstrate habitat opportunities; USGS map used to show the location for each photo:
  1. SB-GM linkage area: one-mile-wide band with virtually no housing – great opportunity; Grapevine Canyon has perennial water; Joshua tree woodland and creosote scrub
  2. SB-SG linkage area: Cajon Wash; I15 impediment; National Forest property on both sides; potential riparian and upland connections; old route 66, railroad tracks; bridged and culvert undercrossings for I15 at four main drainages (best bridge is at Cleghorn Creek with perennial water and direct route into Lone Pine Canyon); vegetation scorched by recent wildfire; SG-Baldy Mesa secondary linkage important
  3. SB-SJ linkage area: low elevation connection across San Gorgonio Pass; possible upland connection through badlands and San Timoteo Canyon; I10 and SR111 are impediments; Morongo Reservation includes upper San Gorgonio River; massive sand and gravel mining operation; development along I10 increasing impediment; many drainages/canyons in lower San Jacinto Mountains; The Wildlands Conservancy recently protected portion of Whitewater River; windfarms near I10

4. SB-LSB linkage area: SR62 main impediment; several drainages cut through Morongo Valley; Mission Creek – good bridges for movement – The Wildlands Conservancy owns portion; desert wash connectivity possible across freeway; possible need for crossing over highway; large band of undeveloped land; natural wetlands in Big and Little Morongo Wash

Claudia Luke, San Diego State University Field Station Programs – *Considerations for Connectivity & Overview of Working Group Session*

Summary: This presentation describes the Santa Ana – Palomar Mountains linkage to allow workshop participants to understand purposes of focal species groups, identification of critical biological issues regarding connectivity, and qualities of species that may be particularly vulnerable to losses in connectivity.

Biography: Claudia Luke received her Ph.D. in Zoology from University of California, Berkeley in 1989. She is a Reserve Director of the Santa Margarita Ecological Reserve, an SDSU Field Station, and Adjunct Professor at San Diego State University. She is on the Board of Directors for the South Coast Wildlands Project and has been the lead over the last two years in conservation planning for the Santa Ana – Palomar Mountain linkage.

- At the November 2000 Missing Linkages conference, participants determined which areas within California needed to be connected to allow species movement
- South Coast Ecoregion workgroup selected criteria to prioritize linkages and connect largest protected lands; planning efforts have progressed for the Santa Ana – Palomar Mountains linkage area - workshops have been held to select focal species
- Global linkage role: preservation of biodiversity hotspot with concentration of endemic species (formed by gradients in elevation, lack of past glaciers, soil diversity)
- Regional linkage role: maintenance of habitat connectivity to prevent extirpations, and considerations for climate change (warmer wetter winters and drier summers may cause extreme floods and wildfires, drier vegetation types may expand to higher elevations)
- Local linkage role: connect protected parcels, considering dispersal methods of focal species, and impacts to habitat specialists, endemics, edge effects, and gene flow
- Focal species approach to functional linkage planning based on Beier and Loe 1992 corridor design (choose appropriate species, evaluate movement needs, draw corridor on map, monitor); focal species are units of movement used to evaluate effectiveness of linkages; wide diversity of species necessary to maintain ecological fabric; collaborative planning effort based on biological foundation and conservation design/delivery
- Choose species sensitive to fragmentation to represent linkage areas; Crooks and Soule 1999 showed that in San Diego as fragment size decreases, mid-sized carnivores increase (mesopredator release), and multiple bird species are lost; must consider associated species in planning, including keystone species important for survival of other species (ex - *Yucca whipplei* pollinated by specific invertebrates)
- Each taxonomic working group will choose a few species, delineate movement needs, record information on natural history, distribution, habitat suitability, current land conditions, key areas for preservation and restoration; consider metapopulation dynamics so that if a species disappears due to disturbance, habitat can be re-colonized
- Focal species data will be displayed on conservation design map and used to guide planning efforts; regional approach to linkages will help project to gain visibility and leverage to work with multiple agencies and organizations

Appendix C: 3D Visualization

The South Coast Wildlands is in the process of producing several flyovers or 3D visualizations of the San Bernardino-Granite Mountains Connection and other linkages throughout the South Coast Ecoregion as part of the South Coast Missing Linkages Project.

The 3D Visualization provides a virtual landscape perspective of the local geography and land use in the planning area. 2002 USGS LANDSAT Thematic Mapper data was used to build a natural color composite image of this study area.

INSTRUCTIONS ON VIEWING FLYOVER

The flyover provided on this CD is an .mpg file (media file) which can be viewed using most popular/default movie viewing applications on your computer (e.g. Windows Media Player, Quick Time, Real One Player, etc).

Simply download the .avi file "3D_Visualization.mpg" from the CD onto your computer's hardrive. Putting the file on your computer before viewing, rather than playing it directly from the CD, will provide you with a better viewing experience since it is a large file.

Double click on the file and your default movie viewing software will automatically play the flyover.

If you cannot view the file, your computer may not have any movie viewing software installed. You can easily visit a number of vendors (e.g. Real One Player, Window Media Player, etc.) that provide quick and easy downloads from their websites.

Please direct any comments or problems to:

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