Habitat Connectivity Planning for Selected Focal Species in the Carrizo Plain

Draft Outline of Full Report

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(other appendices to be added as other tasks are completed)

Section 4
The Focal Species

4.1 Pronghorn antelope

Distribution and Status: Pronghorn antelope (*Antilocapra americana*) are widely distributed in the western United States, Canada, and Mexico. In 1997, it was estimated that there were nearly one million pronghorn distributed among 15 U.S. states and two Canadian provinces (Byers 1997). Historically, pronghorn were common in southern, central, and northeastern California (Yoakum 2004a), and grasslands of the San Joaquin Valley once supported exceptional numbers (Newberry 1855, cited in Yoakum 2004b). Brown et al. (2006) reported that pronghorn were once widely-distributed in plains and valleys on both sides of the Coastal and Peninsular ranges, from Monterey south as far as the Magdalena Plain in Mexico. According to ranchers, pronghorn herds once numbered in the hundreds at the north end of Carrizo Plain (Koch and Yoakum 2002).

However, pronghorn disappeared from many parts of California, including the Carrizo Plain, by the 1940s due to over-hunting and the conversion of native grasslands to croplands (Yoakum 2004b). California Department of Fish and Game (CDFG) has since reintroduced pronghorn throughout portions of their historic range, including the Carrizo Plain. In 1987, 1988, and 1990, a total of over 200 pronghorn were translocated from the shrub-steppes of northeastern California to the Carrizo Plain and surrounding rangelands (Koch and Yoakum 2002, Yoakum 2004b, Longshore and Lowrey 2008). Koch and Yoakum (2002) estimated population size to fluctuate around 50 animals during 1999-2003. In 2008, the population was estimated at approximately 100 animals (R. Stafford, CDFG, unpublished data).

Whereas pronghorn of the Sonoran Desert (*A. a. sonoriensis*) are Federally listed as endangered, pronghorn in some portions of California are a game species subject to regulated hunting. Limited (bucks only) pronghorn hunting occurred on Carrizo Plain during 1996-2001 (Koch and Yoakum 2002).

Habitat Associations: Pronghorn avoid predators by visual detection and speed, and therefore prefer open grasslands and shrub communities with good horizontal visibility, gentle slopes, and few movement obstacles. They inhabit a variety of low-growing vegetation communities, including sagebrush, bitterbrush, grassland, open pinyon-juniper, and alkali desert scrub. Although they typically occupy open, gentle terrain (<10% slope; Ockenfels et al. 1994), pronghorn require some rolling topography or shrubs for cover from inclement weather and concealment of young (Barrett 1981, Ryder and Irwin 1987, Yoakum 2004a). In general, preferred vegetation height averages 38-61 cm, and shrublands with vegetation >88 cm are used less frequently than areas with shorter vegetation (Yoakum 2004a). Based on a literature review, Longshore and Lowrey (2008) suggested that high quality habitat is characterized by slopes ≤ 5%, medium quality habitat typically includes slopes between 5% and 20%, and areas with slopes >20% are low quality. Pronghorn have been documented at elevations from below sea level to 3,353 meters (Yoakum 2004a).

Pronghorn are opportunistic feeders that select forage based on nutritional value, availability, and palatability (Yoakum 2004d). In grasslands, they generally prefer forbs and shrubs over grasses (Yoakum 2004d). Optimal habitat has been described as approximately 40-60% grass, 10-30% forbs, and 5-20% shrubs (Sundstrom et al. 1973, Autenrieth 1978, Yoakum 1978). Pronghorn have been documented to feed on alfalfa and other cultivated plants in California (Hopkins, No date). Use of agricultural fields appears to depend on their proximity to natural lands (Sexton et al. 1981). Pronghorn in Montana were observed to use grain fields within 0.8 km (0.5 mi) of natural rangelands more frequently than grain fields farther from natural rangelands (Cole and Wilkins 1958). In the Carrizo Plain, CDFG biologists also observed pronghorn to restrict use of irrigated agricultural fields to areas within about 0.8 km (0.5 mi) of suitable natural habitat (R. Stafford, CDFG, personal communication).

Pronghorn water requirements are not well understood, and it is likely that needs are related to forage quality and moisture content (Yoakum 2004a). Yoakum (2004a) stated that rangelands with year-round surface water every 1.6 – 3.2 km will support higher densities than areas with fewer water sources. Fences can impede movements, reduce habitat quality, and cause mortalities, depending on fence design, because pronghorn do not readily jump fences (Byers 1997, Yoakum 2004c). Pronghorn movement in Arizona was not impacted by unfenced, paved two-lane roads, but fenced rights-of-way including two- and four-lane roads and railroads acted as barriers and influenced shapes of pronghorn home ranges (Ockenfels et al. 1997).

Spatial Patterns: Pronghorn are gregarious animals found in a wide range of group sizes, depending on such factors as forage quality and quantity, population density, season, and predation risk. On the Carrizo Plain, pronghorn tend to be most gregarious during winter, and are observed in smaller groups during the remainder of the year (R. Stafford, CDFG, unpublished data). The degree of territoriality among males varies among populations, and may be influenced by habitat quality, density, and home range size. Maher (1994) found males on the Carrizo Plain to be less territorial than those in a second research population in Nevada, possibly because the Carrizo Plain population was small, widely dispersed, and recently introduced.

Home range size varies considerably with habitat quality. Annual home range estimates of eight male pronghorn monitored in the rolling plains of Texas ranged from 600 to 1,800 ha (Aiken 2005), whereas another study in semi-desert shrub/grassland habitat in western Texas reported average 3-year home range sizes of 2,509 ha and 4,238 ha for 8 males and 28 females, respectively (Canon 1993). In grassland and juniper habitat in northern Arizona, home ranges of 20 radio-collared animals averaged 8,200 ha for 5 males and 12,400 ha for 15 females (Ockenfels et al. 1997). Although home range estimates are not available for individual pronghorn on the Carrizo Plain, herd range size was estimated at 13,000 ha, based on flight surveys conducted during 1999-2008 (R. Stafford, CDFG, unpublished data). In some populations, territorial males use smaller home ranges than females, and female ranges may overlap multiple male home ranges. For example, in semi-desert shrub/grassland habitat in western Texas, Canon (1993) observed significantly larger home ranges among females than males. In other areas, no gender-based home range differences were detected (O'Gara 2004).

Dispersal distances are not available for individual pronghorn on the Carrizo Plain, but translocated animals in other populations have been documented to travel 50 km and swim across a river to return to their natal ranges (Byers 2003). Pronghorn are seasonally migratory in some regions, and have been reported to move up to 258 km between seasonal ranges (Sawyer et al. 2005).

4.2 Tule elk

Distribution and Status: The tule elk (*Cervus elaphus nannodes*) is the smallest of all elk subspecies in North America. Although the species as a whole is widespread throughout north temperate zones of the world, tule elk are endemic to valleys and foothills of coastal and central California. In the early 1800s, tule elk were found in large numbers in the Sacramento Valley as far north as Red Bluff (Maloney 1945, cited in McCullough 1969) and in large valleys to the west of the Sacramento Valley (McCullough 1969). Along the coast, they were documented in the San Francisco Bay region and in the southern Coast Range, with abundant records in the Monterey Bay area. Historically, elk also occurred in large numbers in the San Joaquin Valley, in particular in the Sacramento-San Joaquin Delta. Tule elk occurred as far south as the Tehachapi Mountains, which apparently form the southern boundary of their distribution, and east to the foothills of the Sierra Nevada (McCullough 1969).

Historically, tule elk were reported to be the predominant herbivore of California's grasslands, sharing the range with deer (*Odocoileus hemionus*), pronghorn antelope, and domestic cattle. Herds of 2000 animals were reported, and it was estimated that 500,000 tule elk may have inhabited the State (McCullough 1969). However, a combination of competition from domestic livestock, market hunting, and land conversion to agriculture caused their numbers to decline precipitously. By 1870, tule elk were nearly extinct, with only one small population remaining in the Buena Vista Lake area in the San Joaquin Valley (McCullough 1969). Subsequent translocations were able to save this subspecies from extinction, and by 1969 three small populations existed in California. By 1996, additional translocations had resulted in 22 populations, distributed primarily across the coastal regions of central California, with one population in Owens Valley to the east (McCullough et al. 1996). In 2007 the state-wide estimate was 3,800 animals (Greco et al. 2009). Tule elk have become a popular game animal in the State, and hunting is allowed at a number of locations, including Carrizo Plain National Monument.

Habitat Associations: In terms of habitat use, tule elk are a specialized subspecies because they inhabit open habitat in semi-arid environments, whereas the species has a whole typically inhabits temperate climates and uses areas of heavy vegetation at least seasonally (McCullough 1969). Typical habitat of tule elk includes large grassland areas, which range from grasslands interspersed with marshy habitats in floodplains to relatively xeric rolling grasslands interspersed with trees and brush stands (McCullough 1969). Tule elk use brush and chaparral habitats if they are in proximity to grasslands (McCullough 1969). Historical records described elk habitat as consisting of "open lands," including extensive plains with rich alluvial soil, interspersed with limited numbers of oaks, sycamores, and ash, and with grasses sometimes knee- or breast-height (McCullough 1969). McCullough (1969) further noted that this subspecies is typically found in areas subject to periodic drought.

Greco et al. (2009) modified existing elk habitat suitability ratings presented in the California

Wildlife Habitat Relationships System (CDFG 2009) to specifically address tule elk habitat needs. They identified annual grasslands, fresh emergent wetlands, and valley foothill riparian habitats as having the highest suitability for tule elk. Other important habitat types included irrigated hayfields, grain crops, row and field crops, and pastures—used primarily for feeding—as well as eucalyptus groves—used primarily for cover. On the Carrizo Plain, CDFG biologists observed tule elk using irrigated agricultural fields within about 0.8 km (0.5 mi) of suitable natural habitat (R. Stafford, CDFG, personal communication).

Tule elk feed on a wide variety of plant species, including annual forbs and grasses, perennial forbs, grasses, and grass-like plants, browse, and even acorns (McCullough 1969). Annual forbs are an important diet item in the spring and early summer, and grasses and sedges are eaten throughout the year (McCullough 1969). Tule elk also eat aquatic vegetation when available. Water requirements likely vary with season, temperature, and moisture content of vegetation.

The impact of fences on tule elk distribution is not well understood. Elk can cross over or go under fences, depending on fence design; however, elk have been known to run into and damage fences when alarmed (McCullough 1969, Ferrier and Roberts 1973). On the Carrizo Plain, as in other tule elk habitat in California, paved roads appear to hinder elk movement, with the result that they often delimit herd ranges (R. Stafford, CDFG, personal communication). Only 13 out of more than 30,000 point locations gathered using GPS collars showed that elk had crossed paved roads, and nearly all observed road crossings occurred immediately after translocated elk were released (R. Stafford, personal communication).

Spatial Patterns: Home range size depends on habitat quality, gender, and annual precipitation (McCullough 1969, Peek 2003). O'Connor (1988) reported mean home range of nine tule elk females in Cache Creek to range from 2,309 to 4,141 ha depending on analysis method used. In comparison, tule elk herds in Contra Costa County (central California) and at Point Reyes National Seashore were reported to use areas of 869 ha and 359 ha, respectively (Pomeroy 1986, Gogan 1986, cited in O'Connor 1986). On the Carrizo Plain, home ranges of radio-collared females ranged from 3,618 ha to 12,640 ha based on minimum convex polygons (R. Stafford, CDFG, unpublished data).

Tule elk are highly social, and may be found in large groups that are dynamic in terms of size and composition (McCullough 1969). Group size depends on season, sex, population, and vegetation density, with the largest groups often observed in open habitats (Knight 1970). Tule elk exhibit pronounced periods of sexual segregation, with males segregated from females for most of the year outside of the autumn breeding period (Peek and Lovaas 1968). Females may be found in large groups with calves and young animals for most of the year, but disperse into smaller groups of 2-10 animals during the spring parturition season (McCullough 1969).

Tule elk do not exhibit the extensive seasonal ranges shifts observed in some other elk subspecies, and are thus not typically considered to be migratory (McCullough 1969). However, herds may exhibit seasonal shifts in response to local forage conditions and annual patterns of plant productivity (McCullough 1969).

Tule elk are capable of moving great distances in short time periods. McCullough (1969) reported that bull elk introduced near the center of the Owens Valley in the 1930s were observed at the north and south ends of the valley, approximately 230 km apart, within one year of release, indicating dispersal of approximately 115 km. On the Carrizo Plain, elk in established herds were observed to move 20 km during a 2-year period, whereas some animals were observed to move 40 km after their initial release (D. Hacker, CDFG, personal communication).

4.3 San Joaquin kit fox

Distribution & Status: Historically, San Joaquin kit foxes were distributed throughout the San Joaquin Valley and adjacent low foothills, from the vicinity of Byron in Contra Costa County to the foothills of the Tehachapi Mountains (Grinnell et al. 1937). By 1930, their range had been reduced by more than half due to habitat conversion to agriculture and other uses, with the largest areas of occupied habitat remaining in the southern and western portions of their original range (Grinnell et al. 1937). By 1975 the pre-1930 estimate of population size (about 8,700 to 12,100) was reduced by 20-43% (USFWS 1983). San Joaquin kit foxes were Federally-listed as endangered in 1967 and State-listed as threatened in 1971, and the population is believed to have declined even more since the 1970s (USFWS 1998). Currently, kit foxes have a very limited range, mostly in foothill areas and arid valleys of the coastal ranges, western Sierra Nevada, and the Tehachapi Mountains (USFWS 1998, Koopman et al. 1998, Thelander et al. 1994). The largest extant populations are in western Kern County in the vicinity of the Elk Hills and Buena Vista Valley, and in the Carrizo Plains area of San Luis Obispo County (USFWS 1998). The Carrizo Plain population is one of three populations designated a high priority for enhancement and protection by the U.S. Fish and Wildlife Service (USFWS 1998).

Habitat Associations: Kit fox distribution is strongly influenced by topography, vegetative cover, prey availability, and predator densities (Grinnell et al. 1937, Egoscue 1962, Daneke et al. 1984, cited in Warrick and Cypher 1998; Haight et al. 2002, Zoellick et al. 1989). Kit foxes primarily inhabit annual grasslands and sparsely vegetated scrub habitats such as alkali sink scrub, saltbush scrub, and chenopod scrub. Other habitats such as open oak savannah, vernal pools, perennial grasslands, alkali meadows and playas are also used (USFWS 1998, B. Cypher, California State University, Stanislaus, personal communication). Kit foxes prefer areas with abundant rodent populations and open environments where they can detect and evade coyotes and other predators (Warrick and Cypher 1998). High kit fox capture rates have been documented in recently burned areas, which was attributed to the openness of the habitat and its affect on predator evasion (Zoellick et al. 1989). Kit foxes can also persist in and adjacent to agricultural areas, such as row crops, irrigated pastures, orchards, and vineyards, as well as vacant lands or open spaces (e.g., parks, golf courses, and flood control areas) within urban areas (USFWS 1998, Cypher and Frost 1999). Among grasslands, kit foxes prefer more open, low-growing, and sparsely vegetated areas, such as *Bromus*-dominated grasslands in drier regions, and tend to avoid taller, denser grasslands such as *Avena*-dominated communities in moister areas (B. Cypher, personal communication).

Kit foxes use dens year-round to escape predators, bear young, and as daytime resting places. Kit foxes may be found on a wide variety of soils, but they prefer loose-textured soils (USFWS 1998) which facilitate burrow construction and tend to support more rodents that are kit fox prey.

San Joaquin kit foxes are typically associated with low elevations on valley floors. Grinnell et al. (1937) placed the upper elevation limit at about 1,200 feet (366 m), but Laughrin (1970) observed kit foxes at 2,400-ft (732 m) elevations during spotlighting surveys, and estimated that kit foxes in the southwestern portion of their range, south of Highway 46, range up to about 2,500 feet (762 m). They are mainly associated with gently sloping and flat terrain. The literature suggests that slopes of 0-5% are ideal, slopes of 5-15% provide fair habitat, and areas with slopes >15% are largely unsuitable (B. Cypher, personal communication). Warrick and Cypher (1998) found a negative relationship between topographic ruggedness and capture rates of kit foxes in Elk Hills and Buena Vista Hills of the Temblor Range.

Spatial Patterns: Kit fox pairs remain together all year and share a home range (USFWS 1998). Home range estimates vary from less than 260 ha to approximately 3,100 ha (Morrell 1972, Knapp 1978, cited in USFWS 1998, Zoellick et al. 1987, Spiegel and Bradbury 1992, White and Ralls 1993). Home range sizes at the Naval Petroleum Reserve averaged 460 ha (Zoellick et al. 2002), whereas home range size of 21 animals on the Carrizo Plain averaged 1,160 ha (White and Ralls 1993). Home range size is largely dependent on prey availability, which can vary annually in relation to precipitation (Haight et al. 2002). The sexes typically do not differ in home range size (White and Ralls 1993, Zoellick et al. 2002). Haight et al (2002) assumed two kit foxes per home range, which they estimated to average 390 ha in good habitat and 780 ha in fair habitat. In optimal habitat, each kit fox family requires approximately 486 ha, with larger space requirements in suboptimal habitats (Cypher et al. 2007).

Dispersal distances vary widely, with male foxes known to travel over 40 km (Haight et al. 2002) and juvenile dispersal from natal dens documented to range from 8 to 96 km (Thelander et al. 1994). Mean dispersal distance of 48 kit foxes at the Naval Petroleum Reserves was 7.8 $\pm$ 1.1 km, with no sex-based differences observed (Scrivner et al. 1987 cited in Koopman et al. 2000). Koopman et al. (2000) found that 33% of animals dispersed from their natal territory, and significantly more males (49%) dispersed than females (24%). Average nightly distance moved during the breeding period (14.6 $\pm$ 1.1 km) was greater than during the pup-rearing (10.7 $\pm$ 1.0 km), and pup dispersal periods (9.4 $\pm$ 1.1 km; Zoellick et al. 2002).

Adult and juvenile kit foxes are known to move through disturbed habitat, including agricultural fields, oil fields, and rangelands, and across highways and aqueducts (Haight et al. 2002). However, major highways and heavily traveled road are obstacles to movement (Cypher et al. 2000). Vehicles are the greatest source of mortality in urban areas, whereas predation, primarily by coyotes, is the primary cause of mortality in most other areas (Cypher et al. 2000, B. Cypher, personal communication). Cypher et al. (2005) examined the effects of 2-lane highways on kit foxes in the Lokern Natural Area, and found no significant negative effects on fox demography or ecology. However, the authors cautioned that increased road density could have a negative impact, citing studies that reported increased swift fox (*Vulpes velox*) mortality with increasing road density (Cypher et al. 2005), selection by bobcats of habitat with lower road density (Lovallo and Anderson 1996), and declining gray wolf habitat suitability with increased road density (Thiel 1985, Jensen et al. 1986).

5.1 Modeling baseline conditions of habitat suitability and connectivity for each focal species

5.1.1 Compilation and refinement of digital data layers

We compiled GIS data layers for the study area, including the following (see Appendix A for details concerning the source, type, scale, and date of each data layer):

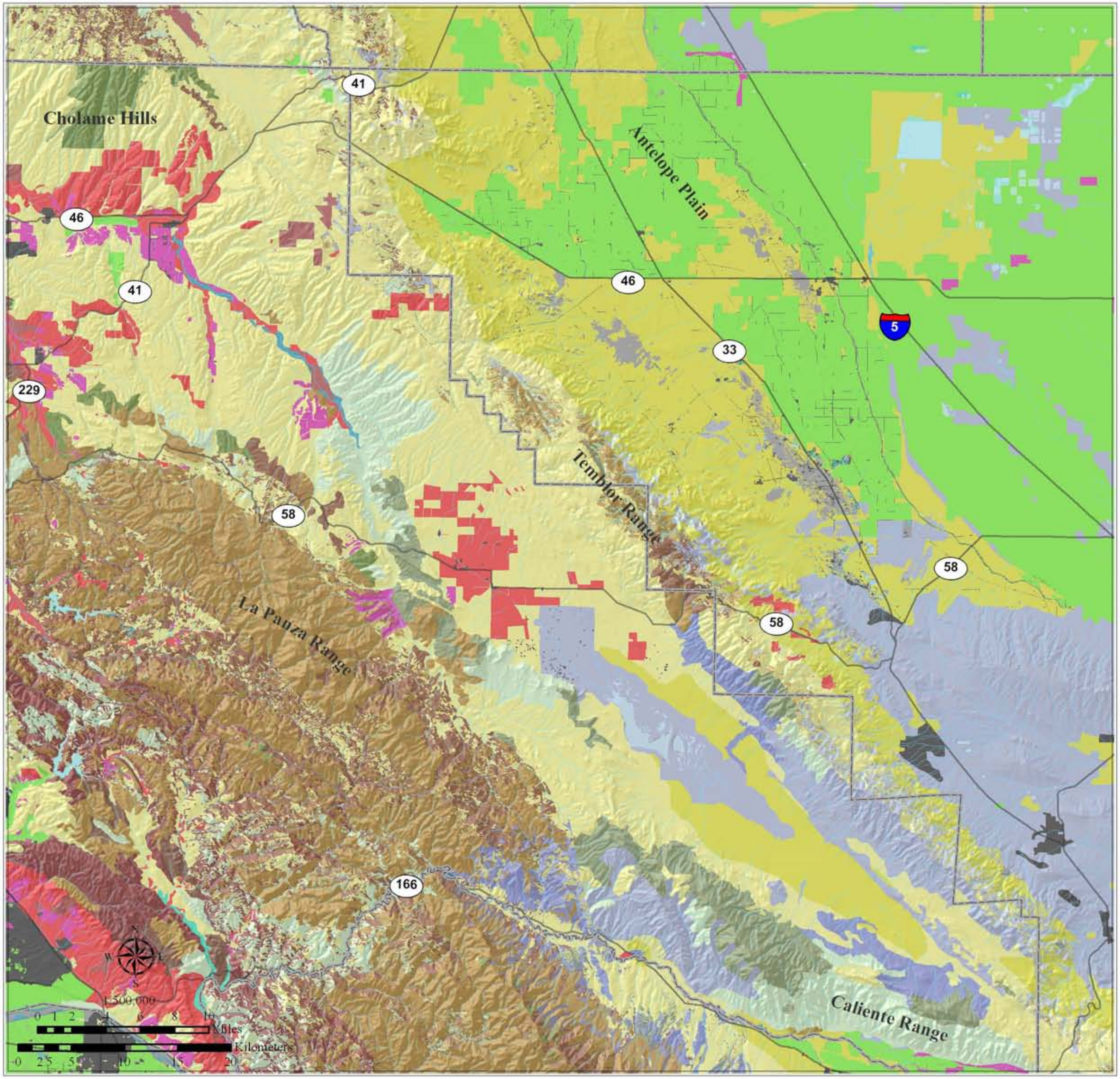
- recent high-resolution aerial photos,
- digital elevation models,
- roads,
- vegetation (including crop and agriculture data from San Luis Obispo and Kern counties),
- protected lands,
- species occurrence data from wildlife agencies, Endangered Species Recovery Program, and California Natural Diversity Database, and
- project boundary data from project proponents.

We manually updated the road and vegetation layers within the study area to be as up-to-date and accurate as possible. For the refined vegetation layer (Figure 1), we compiled vegetation data available from the County of San Luis Obispo website, crop data from San Luis Obispo and Kern counties, and regional vegetation data compiled by the state (CalVeg). We evaluated this compiled vegetation layer in relation to recent high-resolution aerial imagery and made changes where necessary to reflect the most recent land use status. Particular emphasis was placed on agricultural and urban land cover types. For example, we corrected the vegetation classification of some lands that had recently been converted to agriculture or urban but were still shown as natural vegetation in the compiled vegetation data layer. Conversely, areas shown as agriculture or urban within the compiled vegetation layer that had not actually been converted to either land use were changed back to the vegetation type in either the CalVeg or County Vegetation data layer.

Further refinements were made based on input received during the comment period:

- Polygons identified as “undefined agriculture” were assigned specific categories, such as dryland grain crops, irrigated row and field crops, vineyards, and orchards based on aerial imagery and review by CDFG biologists familiar with the area.
- Polygons defined as pasture were examined using imagery to determine if they were irrigated or non-irrigated. All non-irrigated pasture polygons were changed to annual grassland; all irrigated pasture polygons remained as pasture.
- Based on input from field biologists familiar with vegetation in the study area, (B. Cypher, personal communication) we differentiated *Avena*- and *Bromus*-dominated grasslands using precipitation data. Cypher and colleagues (personal communication) had found the 9-inch annual precipitation isocline to be a good threshold for differentiating denser, taller grasses, usually dominated by *Avena*, and generally avoided

Figure 1.
Vegetation
in the Study Area



Vegetation

- Alkali Desert Scrub
- Annual Grassland - Avena
- Annual Grassland - Bromus
- Barren
- Blue Oak Woodland
- Blue Oak-Foothill Pine
- Chamise-Redshank Chaparral
- Closed-Cone Pine-Cypress
- Coastal Oak Woodland
- Coastal Scrub
- Cropland
- Desert Riparian
- Desert Wash
- Dryland Grain Crops
- Eucalyptus
- Freshwater Emergent Wetland
- Irrigated Row and Field Crops
- Juniper
- Lacustrine
- Mixed Chaparral
- Montane Chaparral
- Montane Hardwood
- Montane Hardwood-Conifer
- Orchard and Vineyard
- Pasture
- Perennial Grassland
- Pinyon-Juniper
- Sagebrush
- Sierran Mixed Conifer
- Urban
- Valley Foothill Riparian
- Valley Oak Woodland
- Vineyard
- Wet Meadow
- Highways
- Rivers & Streams
- Hydrography
- County Boundaries

Map Produced By:

SC Wildlands
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by kit fox, from sparser, shorter grasslands, typically dominated by *Bromus*, and generally favored by kit foxes. We therefore downloaded and processed PRISM precipitation data (gridded 30 arc-second [800m] annual normals) for 1971-2000 and classed annual grassland vegetation as *Bromus*-dominated (< 9 inches precipitation) or *Avena*-dominated (≥ 9 inches precipitation).

To create and update the road layer, we first downloaded 2007 Tiger Line road data and evaluated them using recent high-resolution aerial imagery, adding dirt roads not captured by the 2007 Tiger Line data. To delineate paved roads, we used Caltrans highway data and input from CDFG biologists. We then re-evaluated the study area using recent high resolution aerial imagery to identify other paved roads not captured in the Caltrans data. All other roads in the 2007 Tiger Line Data were delineated as dirt roads (Figure 2).

5.1.2 Modeling habitat suitability

We created habitat suitability models for each species by estimating how the species responded to different habitat factors that were mapped at a 30 x 30-m cell resolution. The actual spatial data layers used in each habitat suitability model depended on the species. For example, factors incorporated into the pronghorn antelope model were vegetation type, slope, and road density. (Details of the species-specific models are described in Section 5.1.4.) Within each factor, suitability scores were assigned to each category (e.g., each vegetation type) on a scale of 0 (unsuitable) to 1 (most suitable). For pronghorn and tule elk, habitat suitability was calculated for each 30-m^2 pixel using a Weighted Geometric (Multiplicative) Mean:

$$\text{Suitability} = (S_A^{WA}) * (S_B^{WB}) * (S_C^{WC})$$

where S_A, S_B, and S_C are suitability ratings for factors A, B, and C, respectively, and WA, WB, and WC are the factor weightings.

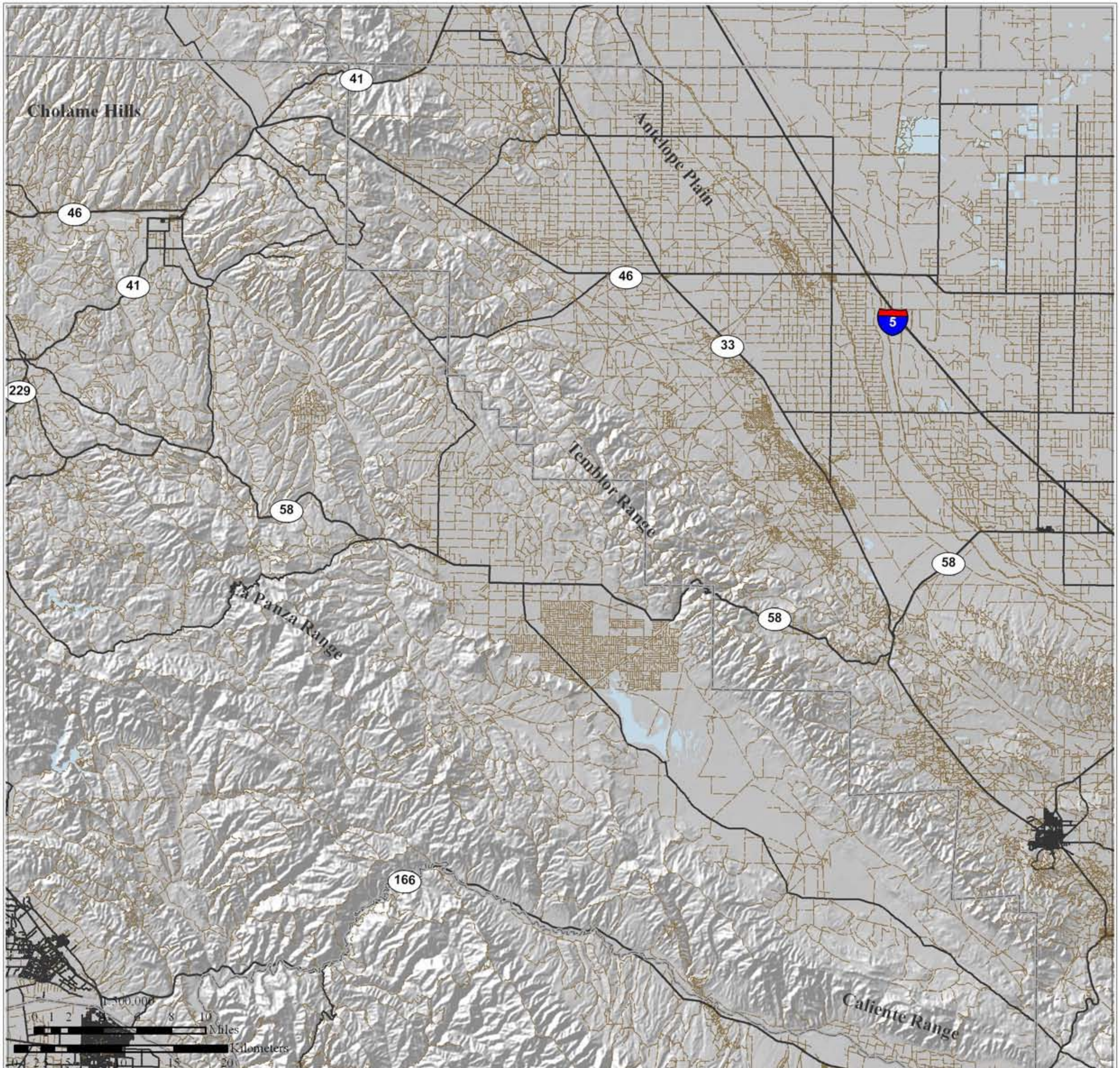
The Weighted Geometric Mean is strongly influenced by low suitability ratings, such that if a score for any class is 0, then suitability of the pixel remains 0 regardless of factor weight or scores for other factors. We divided the resulting suitability values using natural breaks into five classes (low, low to medium, medium, medium to high, and high) for both species.

The habitat suitability model for San Joaquin kit fox applied the model structure and values of Cypher et al. (2007) using our refined map layers. This model used a Weighted Arithmetic (Additive) Mean:

$$\text{Suitability} = (S_A * WA) + (S_B * WB) + (S_C * WC).$$

The Weighted Arithmetic Mean is more compensatory than the Weighted Geometric Mean in that factors with low values can be offset by factors with higher values. Following Cypher et al. (2007) the output was divided into three defined classes: high (≥0.9); medium (≥0.6 but <0.9); and low (<0.6). Additional details concerning habitat suitability analyses are in Section 5.1.4 and Appendix B.

Figure 2.
Roads in the
Study Area



Roads

- Highway
- Other Paved Roads
- Dirt Roads
- County Boundaries
- Hydrography

N
W E
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Lands rated as medium to high by each habitat suitability model were used to identify species-specific habitat *patches* and habitat *cores* based on contiguous area. *Potential core areas* were defined as the amount of contiguous suitable habitat necessary to sustain at least 50 individuals (Beier et al. 2006). Potential cores are probably capable of supporting the species for several generations. 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. 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.

To determine whether the distribution of suitable habitat 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 can disperse twice as far as the longest documented dispersal distance.

5.1.3 Modeling landscape permeability

Landscape permeability analysis is a GIS technique that models the relative cost for a species to move between target areas based on how each species is affected by habitat characteristics, such as topography, elevation, vegetation composition, and road density. This analysis identifies a least-cost corridor, or the best potential route for each species between targeted areas (Craighead et al. 2001, Singleton et al. 2002). The purpose of the analysis is to identify land areas which would best allow the focal species to live in or move through the linkage (Beier et al. 2006).

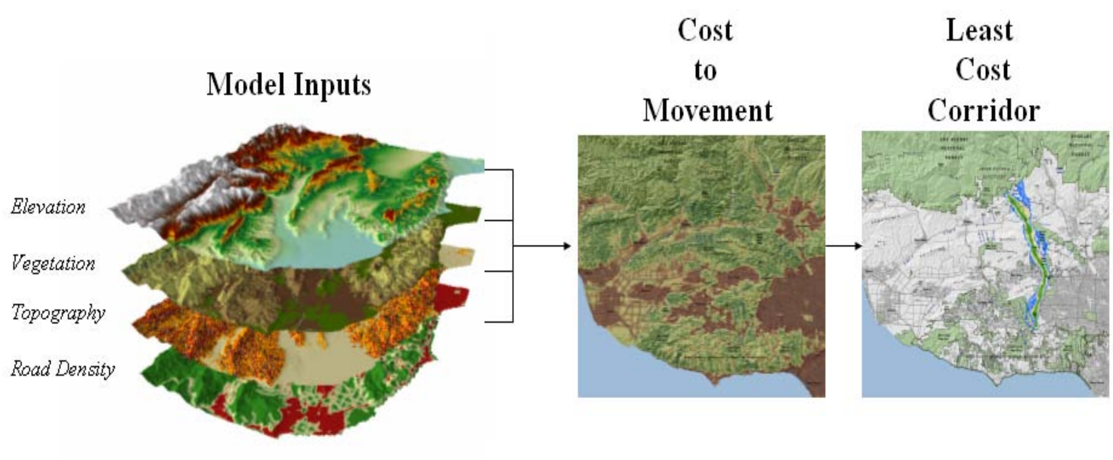


Figure 3. Example permeability model inputs: elevation, vegetation, topography, and road density. Landscape permeability analysis models the relative cost for a species to move between target areas based on how each species is affected by various habitat characteristics.

For each species, the relative cost of travel was calculated using habitat factors considered most influential on that species' movements (selected from among the factors vegetation type, vegetation density, road density, elevation, topographic position, and terrain ruggedness). The factors, class rankings, and weighting values may therefore differ from those used for each species in determining habitat suitability. We derived four topographic classes from elevation and slope models: canyon bottoms, ridgelines, flats, or slopes. Terrain ruggedness was measured as the variance in elevation between each grid cell and its neighboring cells. For tule elk and kit fox, road density was measured as kilometers of paved road per square kilometer (averaged over a 1-km^2 moving window), whereas for pronghorn, road density was measured using both paved and dirt roads. Vegetation density was based on reflectance data derived from satellite imagery (see Section 5.1.4.3 for additional details on this index).

Within each factor, experts assigned each category (e.g., various vegetation categories or categories of road density) a rating between 1 (preferred) and 10 (avoided) based on each species ability to move through areas with these characteristics, as determined from available literature and expert opinion. Cost to movement was then calculated as the Weighted Arithmetic Mean for each species (where cost of movement can be thought of as the inverse of permeability). A unique cost surface (cost raster) was thus developed for each species. The least-cost corridor analysis then maps the relative degree of permeability for a species based on the cumulative travel cost calculated using the cost raster and distance between targeted core areas. We then used a "slice" (or cost contour) of the resulting cost surface based on expert opinion to delineate a least cost corridor that is biologically meaningful for the species.

Performing permeability analyses requires identifying the endpoints (or targets) to be connected. Target Zones were identified at the southern and northern extent of the study area, and target endpoints were selected as medium to high suitable habitat for each focal species within each Target Zone. We used the same Target Zones for all three species. However, we tested some alternative target endpoints within the southern Target Zone for kit foxes. For kit fox, our original southern target endpoint included medium to high quality habitat on both sides of the Temblor Range, which strongly influenced predicted movement corridors to cross from the Carrizo Plain over the Temblor Range to include large swaths of the San Joaquin Valley floor. Kit fox biologists found this result biologically untenable, as they consider the Temblor Range a strong obstacle to kit fox movement, and no kit foxes have ever been observed crossing the range during telemetry studies. We therefore modified the southern target by using only high suitability contiguous core kit fox habitat in the southern Target Zone, and modified the factor ratings and weightings to better reflect kit fox avoidance of very rugged terrain.

Appendix B and Section 5.1.4 describe species-specific model input data and additional details concerning the habitat suitability and landscape permeability analyses.

5.1.4 Species-specific model input data and conceptual basis for model development

5.1.4.1 Pronghorn antelope

Habitat Suitability: We developed a Weighted Geometric (Multiplicative) Mean GIS habitat suitability model using vegetation type, slope, and road density as primary variables, based on information summarized in Section 4.1 and discussions with species experts. The model reflects that pronghorn prefer open terrain, short vegetation, few barriers, and gentle slopes. Because pronghorn use a wider range of elevations (0 to 3,353 meters) than occurs in the study area, elevation was not an input factor.

Habitat suitability ratings (from 0 to 1, with 1 being most suitable and 0 being unsuitable) for individual vegetation, road density, and slope classes were provided by CDFG biologists most familiar with this species on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B). Suitability ratings shown in Appendix B were further refined as follows:

- Within the factor "Slope", categories were based on recommendations by Longshore and Lowrey (2008): slopes > 5% and ≤ 20% were rated as medium suitability (rating = 0.6) and slopes > 20% were rated as low suitability (rating = 0.3). "Flats," ≤ 5% slope by definition, were rated as high suitability (rating = 1.0).
- Irrigated agricultural lands within 0.8 km (0.5 mi) of suitable natural habitat areas (suitability ≥ 0.5) were rated as shown in Appendix B; but irrigated agriculture more than this distance from suitable natural habitat was rated as unsuitable (rating = 0), based on observations that pronghorn only use such fields in proximity to suitable natural habitats (Cole and Wilkins 1958, R. Stafford, CDFG, personal communication).

Habitat use by pronghorn on the Carrizo Plain may not be directly affected by roads, per se, but habitat use may be adversely affected by fences (Ockenfels et al. 1997). Because many roads in the study area, both paved and unpaved, are accompanied by fences, and because a comprehensive fence data layer was not available, the pronghorn habitat suitability model considered areas with a high road density to be less suitable than less-roaded areas, and this factor did not differentiate between paved and unpaved roads.

Although distance to water may influence pronghorn habitat suitability, especially during summer (Yoakum 2004a; Section 4.1), a complete map of water sources (including both natural and artificial water sources) was not available for this study area and we thus did not include water in our model.

Appendix B lists the category scores and factor weights for each factor, provided based on expert opinion by R. Stafford and D. Hacker (CDFG, personal communication). Each factor was weighted from 0% to 100%, such that all weights must sum to 100%. Habitat suitability was calculated for each 30-m^2 pixel in the study area as the weighted geometric mean of scores for that pixel:

$(\text{Vegetation Score}^{0.35}) * (\text{Road Density Score}^{0.10}) * (\text{Topography Score}^{0.55}) = \text{Habitat Suitability}.$

Habitat Patches and Cores: Potential Habitat Patches and Cores were identified as contiguous polygons of medium, medium-high, and high suitability habitat meeting the following size criteria. Minimum patch size (defined as the area of suitable habitat capable of supporting at least two individuals) was estimated as 13,000 ha based on estimated herd range size on the Carrizo Plain (R. Stafford, CDFG, unpublished data). Core areas (defined as areas potentially supporting 50 or more individuals) were estimated to be ≥ 65,000 ha (herd range x 5) based on expert opinion (R. Stafford and D. Hacker). Thus, patch size was defined as ≥ 13,000 ha but < 65,000, and core areas were defined as ≥ 65,000 ha. Any suitable habitat < 13,000 ha was defined as less than a patch. These areas may serve as stepping stones between potential patches and core areas. Dispersal distance was defined as 100 km for the patch configuration analysis for pronghorn.

Landscape Permeability: For permeability analysis, we identified areas to be connected as habitat of medium to high suitability within two Target Zones: one in the southeastern portion of the study area (including Carrizo Plain National Monument [CPNM], Carrizo Plain Ecological Reserve, Bureau of Land Management parcels contiguous with the National Monument and Ecological Reserve, and small portion of the Bittercreek National Wildlife Refuge) and one in the northwestern portion of the study area, north of the westernmost extent of State Route 46 and west of State Route 33. These Target Zones were selected to represent large intact landscapes that included important habitat for each species and that should remain connected to assure long-term population viability. The Target Zone in the southeast is known to support a population of pronghorn, and current pronghorn distribution is known to extend from this area northwest beyond the State Route 46-State Route 41 intersection. Although the Target Zone in the northwestern portion of the study area is not currently protected, it represents a large intact landscape that connects to intact lands beyond the northwest extent of our study area. As such, maintenance of connectivity from CPNM to the northwestern zone is assumed to provide pronghorn with important connectivity to areas beyond this zone.

Permeability ratings were provided by CDFG biologists most familiar with pronghorn on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B). They were combined using the following Weighted Arithmetic Mean equation, which represents cost of movement (the inverse of permeability):

(Vegetation Score * 35%) + (Road Density Score * 10%) + (Topography Score * 55%) = cost.

The equation reflects that pronghorn are most likely to move through open terrain, with short vegetation, few barriers, and gentle slopes, but that these variables may influence pronghorn movements in a more compensatory way than was assumed for defining suitable habitat for foraging, breeding, etc. Because pronghorn use a wider range of elevations (0 to 3353 meters) than occur in the study area, elevation was not an input factor into the permeability model.

5.1.4.2 Tule elk

Habitat Suitability: We developed a Weighted Geometric (Multiplicative) Mean GIS habitat suitability model using vegetation type and road density as primary variables, based on information summarized in Section 4.2 and discussions with species experts. The model reflects that tule elk prefer large grassland areas, freshwater emergent wetlands, and valley foothill riparian habitat, but that they also use a wide variety of other habitats including agricultural lands, open brush habitats, and dispersed stands of oaks, sycamore, eucalyptus and other trees. The presence of paved roads influences tule elk movement and appears to delimit some herd ranges on the Carrizo Plain (Section 4.2); thus the model includes density of paved roads as a key input. The habitat suitability model considered areas with a high road density to be less suitable than less-roaded areas.

Habitat suitability ratings (from 0 to 1, with 1 being most suitable and 0 being unsuitable) for individual vegetation and road density classes were provided by CDFG biologists most familiar with this species on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B). Suitability ratings shown in Appendix B were further refined as follows:

- Irrigated agricultural lands within 0.8 km (0.5 mi) of suitable natural habitat areas (suitability ≥ 0.3) were rated as shown in Appendix B; but irrigated agriculture more than this distance from suitable natural habitat was rated as unsuitable (rating = 0), based on observations that tule elk only use such fields in proximity to suitable natural lands (R. Stafford, CDFG, personal communication).

Tule elk use a variety of topographic land forms and a wide range of elevations relative to areas available within our study area, so topographic position and elevation were not included in the model. Because the impact of fences on tule elk habitat suitability is not well understood, and a comprehensive fence data layer was not available for the study area, we did not include fences as an input to our model. Similarly, because water needs of tule elk are not well understood, and a complete map of water sources (including both natural and artificial water sources) was not available for this study area, we did not include water in our model.

Appendix B lists the category scores and factor weights for each factor, provided based on expert opinion by R. Stafford and D. Hacker (CDFG, personal communication). Each factor was weighted from 0% to 100%, such that all weights must sum to 100%. Habitat suitability was calculated for each 30-m^2 pixel in the study area as the weighted geometric mean of scores for that pixel:

(Vegetation Score$^{0.50}$) * (Road Density Score$^{0.50}$) = Habitat Suitability

Habitat Patches and Cores: Habitat Patches and Cores were identified as contiguous polygons of medium, medium-high, and high suitability habitat meeting the following size criteria. Minimum patch size (defined as the area of suitable habitat capable of supporting at least two individuals) was estimated as 3,600 ha based on the minimum home range size observed on the Carrizo Plain (R. Stafford, CDFG, unpublished data). Because elk are gregarious, and home range estimates come from animals living in natural groups, we assumed that one home range could support at least two individuals. Core areas (defined as areas potentially supporting 50 or more individuals) were estimated to be ≥ 63,000 ha (the largest home range observed on the Carrizo Plain x 5) based on expert opinion (R. Stafford and D. Hacker). Thus, patch size was defined as ≥ 3,600 ha but < 63,000, and core areas were defined as ≥ 63,000 ha. Any suitable habitat < 3,600 ha was defined as less than a patch; these areas may serve as stepping stones between potential patches and core areas. Dispersal distance was defined as 80 km for the patch configuration analysis for tule elk.

Landscape Permeability: For permeability analysis, we identified areas to be connected as habitat of medium to high suitability within two Target Zones: one in the southeastern portion of the study area (including Carrizo Plain National Monument [CPNM], Carrizo Plain Ecological Reserve, Bureau of Land Management parcels contiguous with the National Monument and Ecological Reserve, and small portion of the Bittercreek National Wildlife Refuge) and one in the northwestern portion of the study area, north of the westernmost extent of State Route 46 and west of State Route 33. These Target Zones were selected to represent large intact landscapes that included important habitat for each species and that should remain connected to assure long-term population viability. The Target Zone in the southeast is known to be used by tule elk, and elk distribution extends from this area northwest beyond the State Route 46-State Route 41 intersection. Although the Target Zone in the northwestern portion of the study area is not currently protected, it represents a large intact landscape that connects to intact lands beyond the northwest extent of our study area. As such, maintenance of connectivity from CPNM to the northwestern zone is assumed to provide tule elk with important connectivity to areas beyond this zone.

Permeability ratings were provided by CDFG biologists most familiar with tule elk on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B) and combined using the following Weighted Arithmetic Mean equation, which represents cost of movement (the inverse of permeability):

(Vegetation Score * 50%) + (Road Density Score * 50%) = cost.

The equation reflects that elk movement will mostly be influenced by vegetation and density of paved roads and that the influence of these two factors should be relatively equal and compensatory. Because tule elk use a wide range of elevation and topographical terrain types, relative to what is available in our study area, elevation and topographical position were not used as input factors into the permeability model.

5.1.4.3 San Joaquin Kit fox

Habitat Suitability: We determined habitat suitability for San Joaquin kit fox using methods developed by Cypher et al. (2007). This habitat suitability model was found to have good predictive power when compared to field data on fox distribution (B. Cypher, personal communication). The model, which was based on the weighted sum of vegetation type, topographic ruggedness, and vegetation density, reflects that kit foxes use gentle open terrain, primarily within grasslands and open scrub habitats, and that they select sparse versus dense grasslands (Section 4.3).

Habitat suitability ratings (from 0 to 1, with 1 being most suitable and 0 being unsuitable) for individual vegetation classes in the study area were provided by kit fox expert, B. Cypher (personal communication; Appendix B).

In addition to vegetation community classes, the model weighted suitability of natural lands by terrain ruggedness (Valentine et. al. 2004, Cypher et al. 2007). Research on kit foxes at Naval Petroleum Reserves in California has shown terrain ruggedness as a “consistent factor that affected capture rates of kit foxes,” with foxes most abundant in areas of low topographic ruggedness (Warrick and Cypher 1998). Terrain ruggedness was classified using a 30-m digital elevation model and classifying areas as rugged according to elevation differences between each grid cell and its neighboring cells. The resulting values were then reclassed into four classes with values of 0 to 1 with high values (lowest ruggedness) being the most suitable.

The model used reflectance data based on satellite imagery in the form of a Normalized Difference Vegetation Index [NDVI] as an index of vegetation density. The NDVI was derived from remote sensing imagery that compares visible and near infrared radiation to estimate "greenness" or vegetation density relative to bare ground. Each cell was assigned a value based on a composite dataset of mean values from 2001-2006. NDVI values were then reclassed to suitability values ranging from 0 to 1 with high values being most suitable, using known locations of kit fox to guide classification (Cypher et al. 2007, S. Phillips, California State University, Stanislaus, personal communication).

Although San Joaquin kit fox distribution may be influenced by elevation, we assumed that inclusion of vegetation type and terrain ruggedness in the suitability model would likely account for elevational influences.

Habitat suitability was calculated for each 30-m^2 pixel in the study area using the following weighting equation, based on expert opinion (B. Cypher, personal communication):

(Vegetation Score * 50%) + (Terrain Ruggedness Score * 25%) + (Vegetation Density Score * 25%) = Habitat Suitability.

Following Cypher et al. (2007) we reclassed the continuous habitat suitability scores into three suitability classes: low, medium, and high.

Habitat Patches and Cores: Potential Habitat Patches and Core Areas were identified as contiguous polygons of medium to high suitable habitat meeting the following size criteria. Minimum patch size (defined as the area of suitable habitat capable of supporting at least two individuals) was estimated as 486 ha, based on the estimate that this area could support one kit fox family in optimal habitat (Cypher et al. 2007). Core areas (defined as areas potentially supporting 50 or more individuals) were estimated to be ≥ 12,150 ha (family area x 25). Thus, patch size was defined as ≥ 486 ha but < 12,150, and core areas were defined as ≥ 12,150 ha. Any suitable habitat < 486 ha was defined as less than a patch; these areas may serve as stepping stones between potential patches and core areas. Dispersal distance was defined as 192 km for the patch configuration analysis for kit fox.

Landscape Permeability: For the landscape permeability analysis, we identified areas to be connected as habitat of high suitability core habitat within the Target Zone in the southeastern portion of the study area (including Carrizo Plain National Monument [CPNM], Carrizo Plain Ecological Reserve, Bureau of Land Management parcels contiguous with the National Monument and Ecological Reserve, and small portion of the Bittercreek National Wildlife Refuge), and medium to high suitable habitat within the Target Zone in the northwestern portion of the study area, north of the westernmost extent of State Route 46 and west of State Route 33. These Target Zones were selected to represent large intact landscapes that included important habitat for each species and that should remain connected to assure long-term population viability. The Target Zone in the southeast is known to support kit foxes, and their distribution is known to extend from this area northwest beyond the State Route 46-State Route 41 intersection. Although the Target Zone in the northwestern portion of the study area is not currently protected, it represents a large intact landscape that connects to intact lands beyond the study area. As such, maintenance of connectivity from CPNM to the northern zone is assumed to provide kit foxes with important connectivity to areas beyond this zone.

Our model for habitat permeability for kit foxes is based on vegetation, terrain ruggedness, vegetation density, and road density to reflect that kit foxes use areas of gentle terrain in open vegetation associations such as grasslands and open scrub habitats, and that they tend to avoid densely vegetated areas. Furthermore this model reflects that increased road density may reduce permeability.

We ran two versions of the landscape permeability model for kit fox, one using factor ratings for habitat suitability, and one using ratings specifically developed for permeability. These sets of ratings can differ because, for example, kit fox may easily move through some habitats they don't generally use for denning or foraging (B. Cypher, personal communications). The suitability and permeability ratings were both provided by kit fox expert, B. Cypher (personal communication; Appendix B). Previous research conducted by Cypher et al. (2007) used permeability ratings rather than habitat suitability ratings for conducting landscape permeability analyses for kit fox. Both versions combined the ratings using the following weighting equation, which represents cost of movement (the inverse of permeability):

(Vegetation Score * 40%) + (Road Density Score * 5%) + (Terrain Ruggedness Score * 50%) + (Vegetation Density Score * 5%) = cost.

6.1 Task 1: Baseline conditions of habitat suitability and connectivity for each focal species

6.1.1 Habitat Suitability

6.1.1.1 Pronghorn antelope

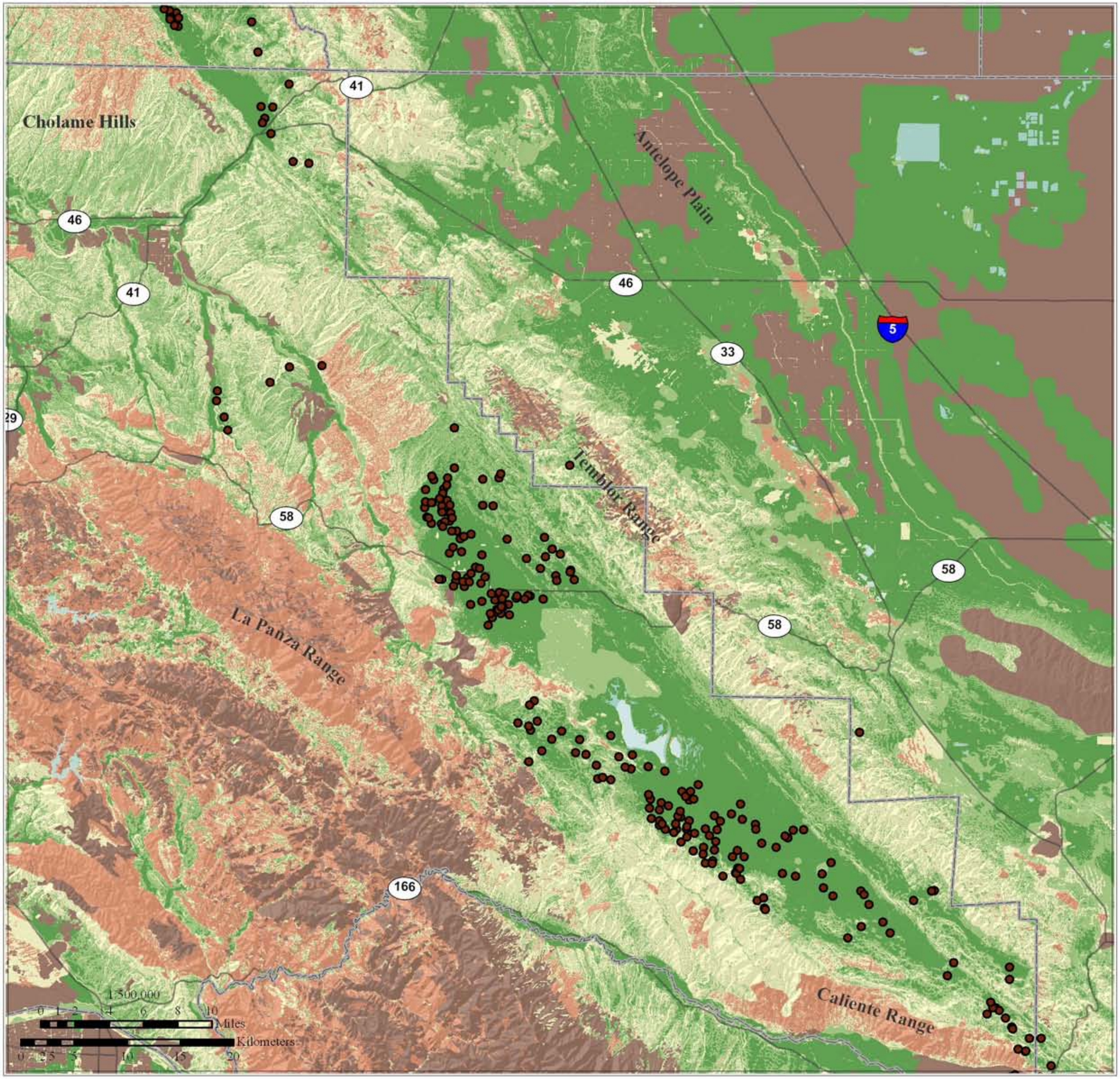
Suitable habitat for pronghorn antelope in the study area is largely restricted to open vegetation communities in gentle terrain. The model identified abundant medium to high suitable habitat for this species on both sides of the Temblor Range (Figure 4). The most extensive areas of highly suitable habitat are in the open grasslands and scrub habitats on the floor of the Carrizo Plain and San Joaquin Valley. Modeled high-value habitat corresponds well with the distribution of sightings in the Carrizo Plain and Cholame Valley. Some agricultural lands were also identified as medium to high suitability, with irrigated row and field crops becoming unsuitable more than 0.8 km from natural suitable lands with suitability ≥ 0.5. Highly roaded portions of the Carrizo Plain, which would otherwise be modeled as high-value habitat, appear as medium-high. Habitat for pronghorn antelope generally becomes less suitable southwest of the La Panza Range in the southwestern portion of the study area and unsuitable in the dense agriculture lands on the San Joaquin Valley floor and in the Santa Maria Valley in the southwestern portion of the study area.

The patch size analysis identified the majority of medium to highly suitable habitat in the study area as potential core areas for pronghorn, with a few patches delineated in the southwestern and northeastern portions of the study area (Figure 5). All potential core areas and habitat patches are within the species dispersal distance (figure not shown), although barriers to movement may exist between areas of suitable habitat.

6.1.1.2 Tule elk

Suitable habitat for tule elk is widespread in the study area in grassland, meadow, scrub, brush, woodland, and riparian communities as well as some agricultural types, such as dryland grain crops and irrigated row and field crops. The most highly suitable habitat primarily follows the *Avena*-dominated annual grasslands and those irrigated row and field crops within 0.8 km of other natural habitats suitable (≥ 0.3) for tule elk (Figure 6). The majority of medium to high suitable habitat occurs in a wide swath from the northwest to southeast of the study area between the La Panza Range and Interstate 5. Other suitable habitats of note occur at the north end of the Caliente Range near Carrizo Canyon; at the base of the La Panza Range on the coastal side along the Salinas River; and along the Cuyama River, Alamo Creek, Nipomo Valley, and Canyon de los Alisos in the southwestern portion of the study area. Areas of medium to high suitable habitat are consistent with sightings of tule elk. Chaparral, montane hardwood and conifer habitats are less suitable for tule elk, as are orchards, vineyards, and dense irrigated agriculture beyond 0.8 km of other suitable natural habitats. Paved roads and habitats in the immediate

**Figure 4.
Habitat Suitability
for
Pronghorn antelope**



Degree of Suitability

- High
- Med-High
- Med
- Low-Med
- Low
- Pronghorn Sightings
- Highways
- County Boundaries
- Hydrography

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W E
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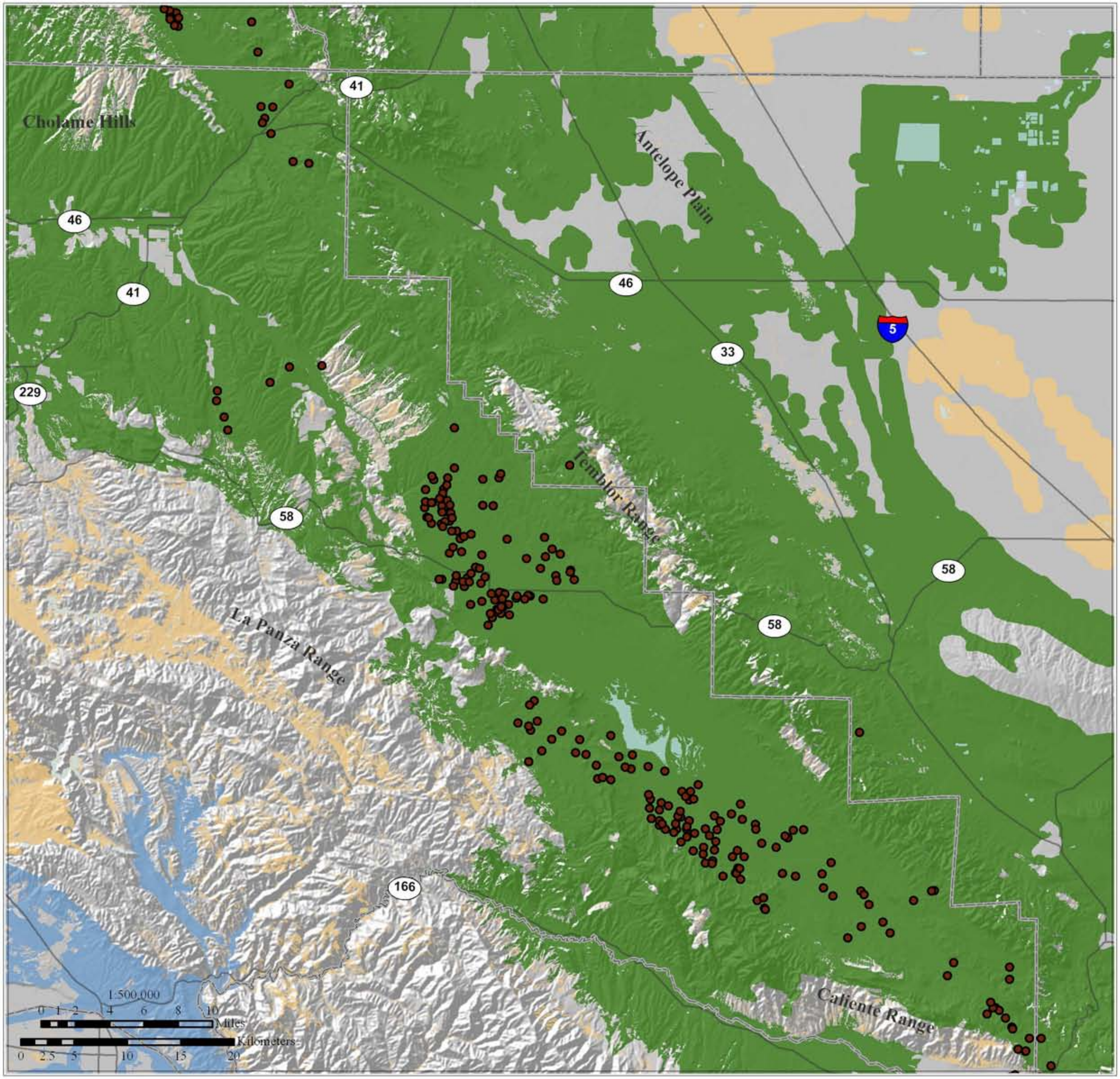
Map Produced By:

SC Wildlands
Science & Collaboration for Connected Wildlands

Figure 5.
Potential Cores & Patches
for
Pronghorn antelope

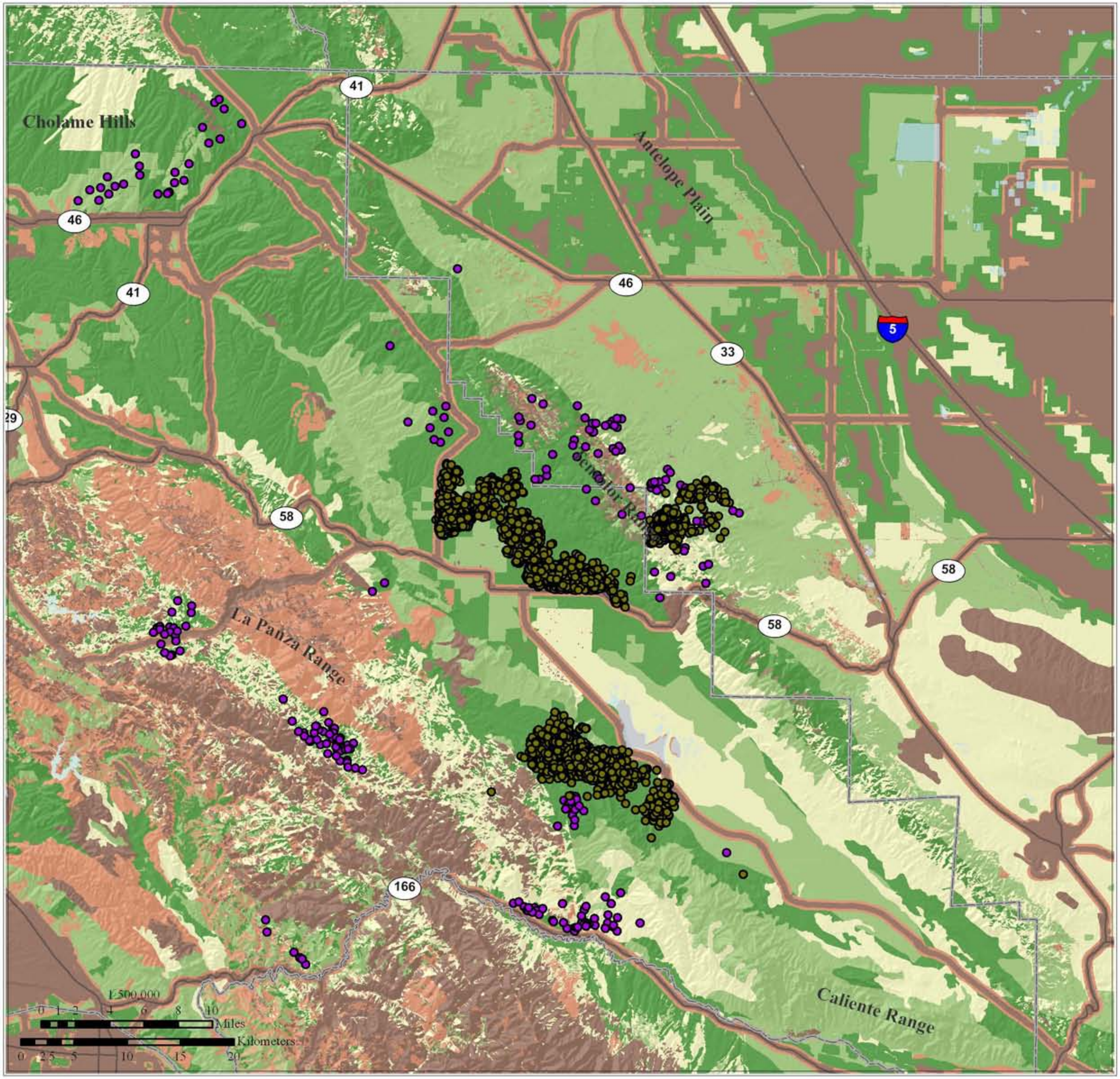


Core
Patch
< Patch
Pronghorn Sightings
Highways
County Boundaries
Hydrography

Map Produced By:

SC Wildlands
Science & Collaboration for Connected Wildlands

Figure 6.
Habitat Suitability
for
Tule elk



Degree of Suitability

- **High**
- **Med-High**
- **Med**
- **Low-Med**
- **Low**
- **Collared Sightings**
- Flight Sightings
- **Highways**
- **County Boundaries**
- **Hydrography**

Map Produced By:

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vicinity of these roads are also unsuitable for tule elk and appear to restrict some herd ranges on the Carrizo Plain, which is evident in the road-constrained distribution of telemetry points on Figure 6.

The patch size analysis identified one potential core area within the analysis extent that is generally bound on the north by State Route 46 and Bitterwater Valley Road, on the east by State Route 33, on the south by State Route 166, and on the west by the La Panza Range (Figure 7). Lands northwest of the State Route 46 and 41 intersection, currently identified as a patch, would also be considered a potential core area if the analysis window extended beyond the study area (R. Stafford, personal communication). Other significant patches occur in between these two core areas, between State Route 33 and Interstate 5 and south of State Route 166, which would have been contiguous with the core areas if not for the paved roads that fragment these areas of medium to high suitable habitat. Additional patches were delineated to the southwest of the La Panza Range. All potential core areas and habitat patches are within the species dispersal distance (figure not shown), although barriers to movement may exist between areas of suitable habitat.

6.1.1.3 San Joaquin kit fox

Suitable habitat for kit fox in the study area is somewhat limited, being primarily restricted to grassland and scrub habitats in gentle terrain on valley floors. The most highly suitable habitat largely follows the drier, *Bromus*-dominated annual grassland and alkali desert scrub habitats in the Carrizo Plain south of State Route 58 and on the San Joaquin Valley side of the Temblor Range (Figure 8). Areas identified as medium suitability for kit fox are primarily *Avena*-dominated grassland and scrub habitats with low topographic ruggedness. These habitats generally occur on the lower slopes and at the base of Temblor Range, around the base of the northern extent of the Caliente Range, straddling State Route 58, in the Cholame Valley, and in scattered patches on gentle terrain between State Routes 58 and 46. All other portions of the study area were considered unsuitable for kit fox.

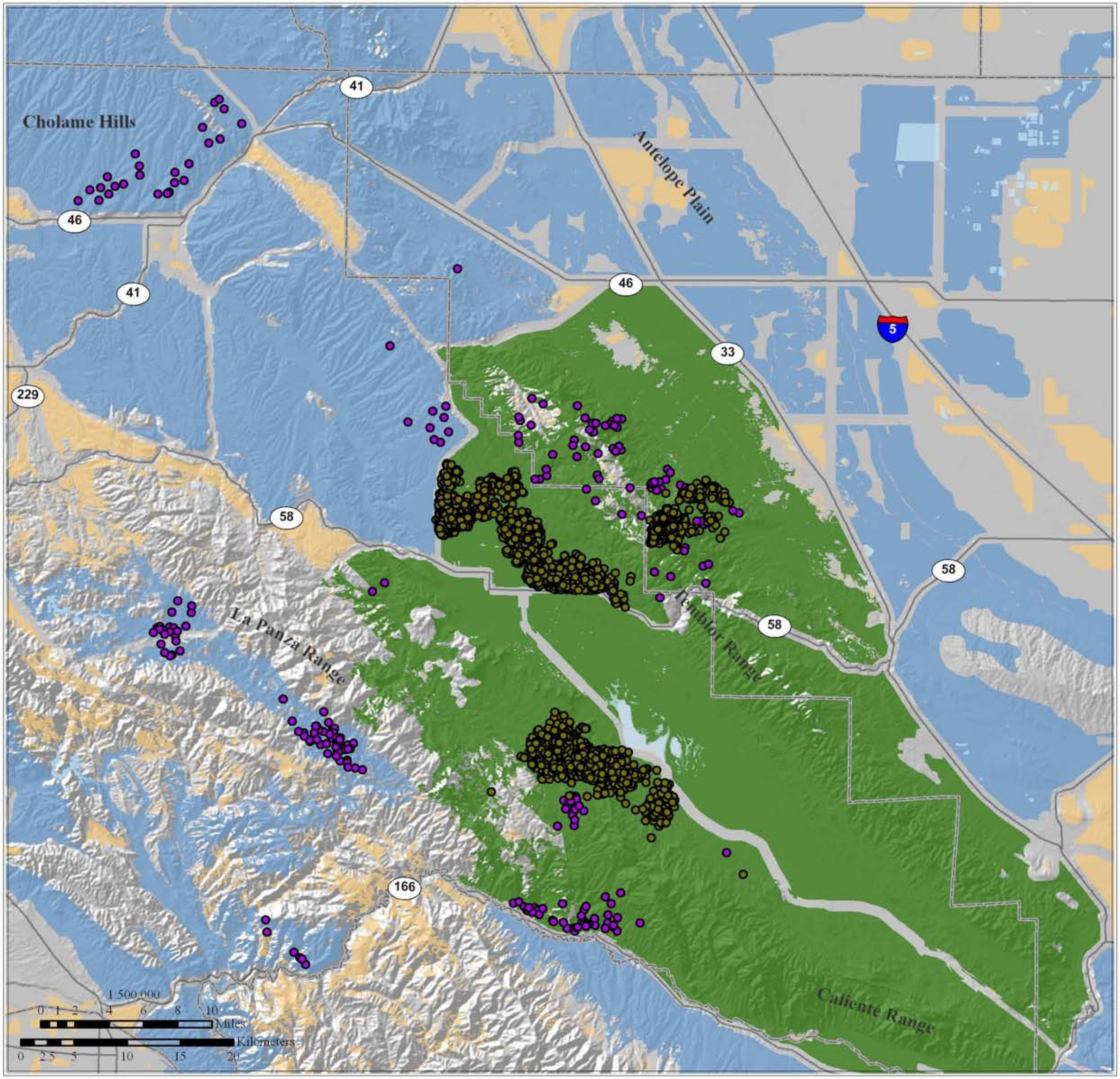
The majority of medium to high suitable habitat in the study area is in large enough continuous areas to serve as potential core areas for kit fox (Figure 9). Some significant patches of suitable habitat were delineated to the west of Simmler Bitterwater Road and to the northeast of the junction of State Routes 46 and 33. All potential core areas and habitat patches are within the species dispersal distance (figure not shown), although barriers to movement may exist between areas of suitable habitat.

6.1.2 Habitat Permeability

6.1.2.1 Pronghorn antelope

The least-cost corridor for pronghorn antelope between the northern and southern Target Zones varies in width from approximately 19 to 26 km using the most permeable 5% portion of the landscape (Figure 10). The most permeable path extends through highly suitable habitat (mostly Avena-dominated annual grassland and dryland grain crops on gentle terrain) from the western

**Figure 7.
Potential Cores & Patches
for
Tule elk**



Core
Patch
< Patch
Collared Sightings
Flight Sightings
Highways
County Boundaries
Hydrography

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Map Produced By:

SC Wildlands
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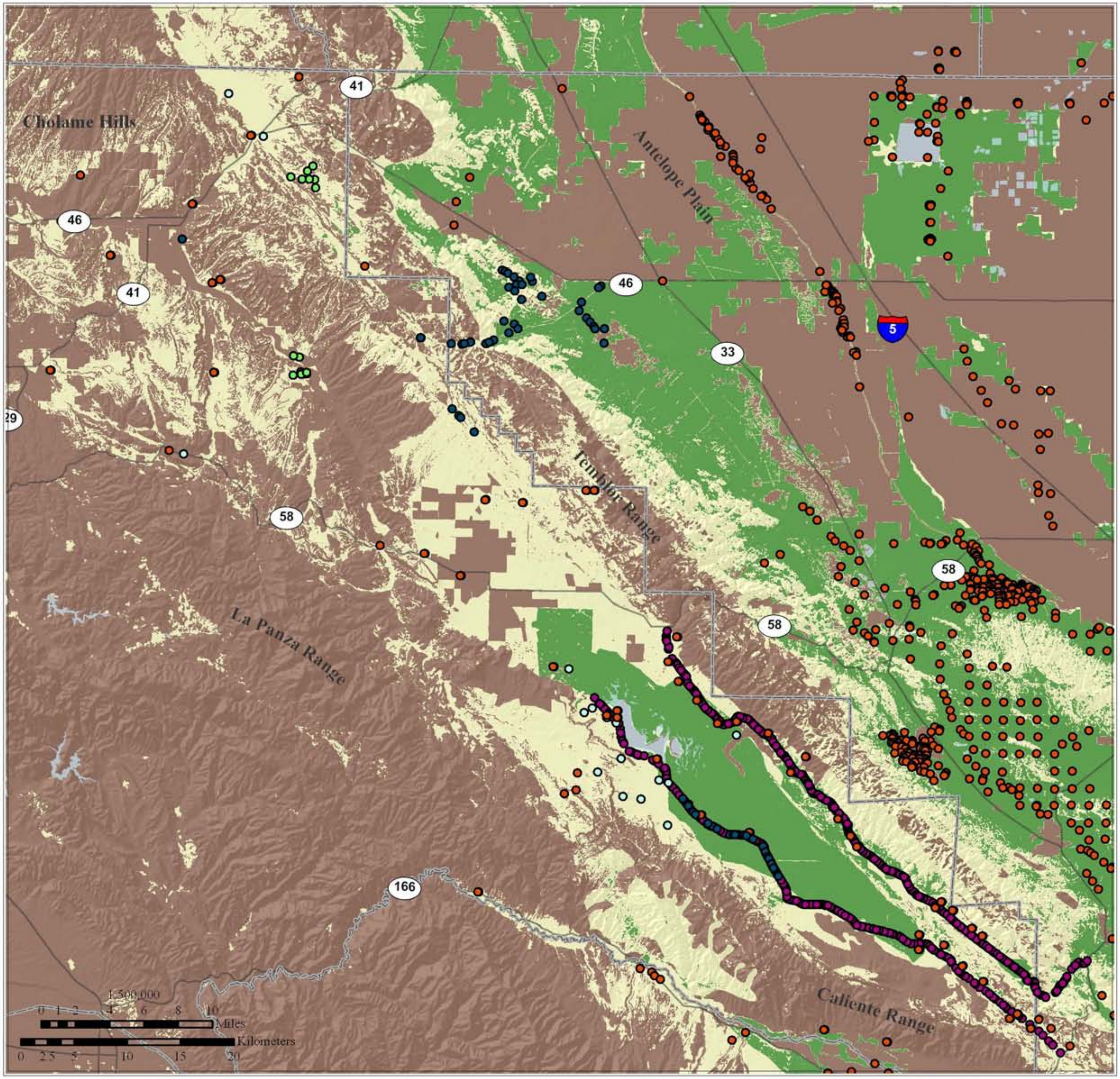
Figure 8
Habitat Suitability
for
San Joaquin kit fox



Degree of Suitability

- **High**
- **Med**
- **Low**
- **Kit Fox Sightings**
- ESRP Kit Fox Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB Kit Fox
- **Highways**
- **County Boundaries**
- **Hydrography**

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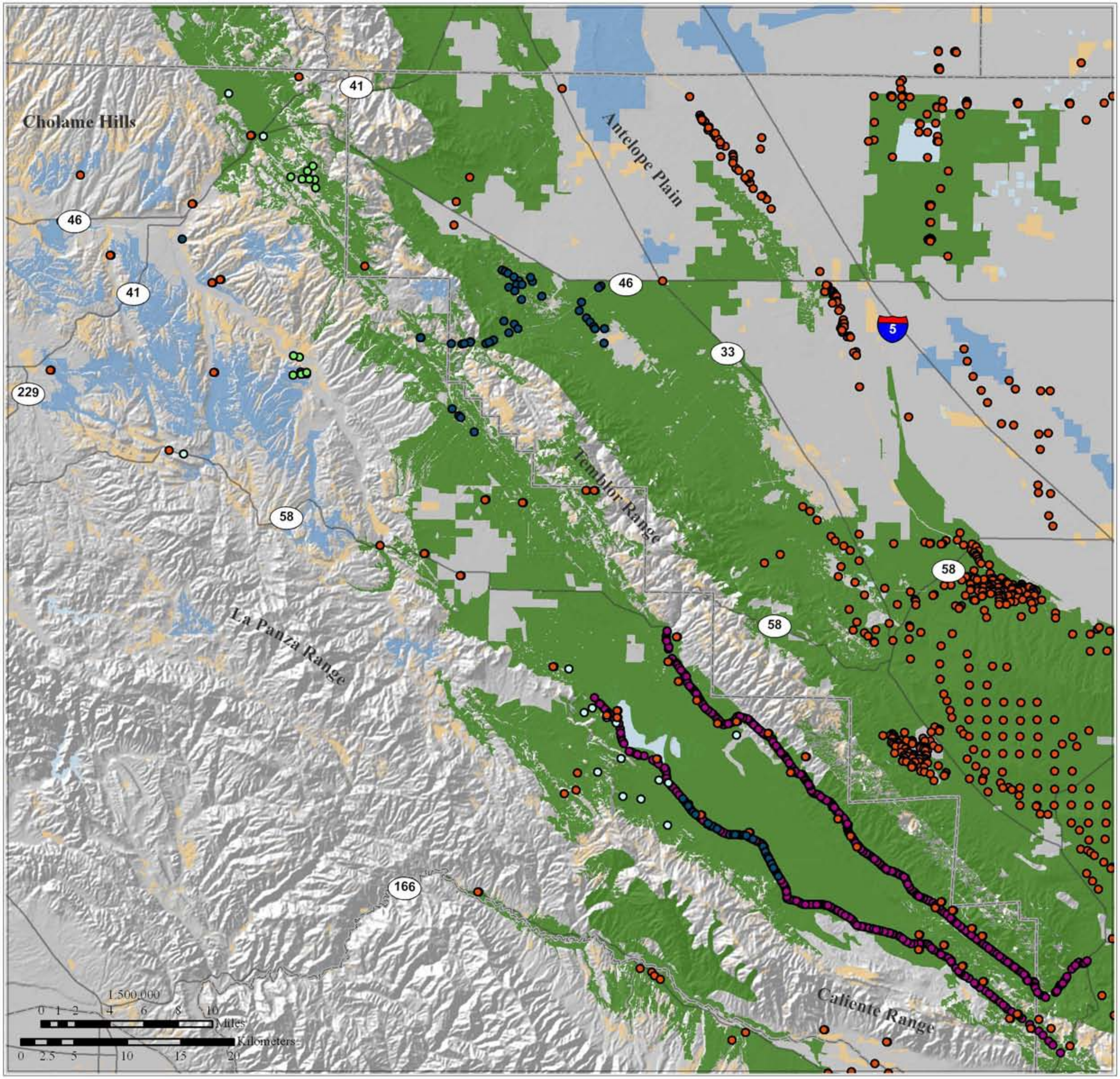
Map Produced By:

SC Wildlands
Science & Collaboration for Connected Wildlands

**Figure 9.
Potential Cores & Patches
for
San Joaquin kit fox**



portion of the southern Target Zone. There are many fences through this area (Figure 10 inset). It is possible that pronghorn may be able to negotiate many of these fences but without more details about their design (height, wire spacing, etc) it is difficult to say anything conclusive. Ongoing efforts, such as those by CDFG and volunteers, to make fences more "pronghorn-friendly" (by raising the bottom wires) and to remove old field fencing, should be continued and expanded. A second, moderately permeable path branches off toward the north over the Temblor Range where grasses predominate, toward the easternmost part of the northern target zone.

6.1.2.2 Tule elk

The least cost corridor for tule elk between the northern and southern Target Zones varies in width from about 9 to 17 km using the most permeable 2% portion of the landscape (Figure 11). It is generally bound by the Temblor Range on the east and by the La Panza Range and Bitterwater Road on the west. The most permeable path extends from the center of the southern Target Zone and follows the highest quality habitat between the two Target Zones; it occurs entirely to the east of Bitterwater Road. A secondary route of moderate permeability follows highly suitable habitat to the west of Bitterwater Road.

6.1.2.3 San Joaquin kit fox

The least cost corridor for kit fox based on habitat suitability ratings between the northern and southern Target Zones ranges in width from approximately 5 to 20 km using the most permeable 1% portion of the landscape (Figure 12). The most permeable route follows the alkali desert scrub habitat out of Carrizo Plain National Monument in the southern Target Zone and then heads in a northeastern direction over the Temblor Range following Carneros Canyon to high quality habitat on the San Joaquin Valley side of the Temblors. A secondary route of moderate permeability extends from the eastern side of the southern Target Zone over the Temblor Range via a dirt road called Hurricane Road to high quality habitat on the San Joaquin Valley side of the Temblor Range, which joins the most permeable route. Kit fox biologists found the results of the permeability analysis based on habitat suitability ratings biologically untenable, as they consider the Temblor Range a significant barrier to kit fox movement, and no kit foxes have ever been observed crossing the range during telemetry studies.

The least cost corridor for kit fox based on permeability ratings between the northern and southern Target Zones ranges in width from approximately 7 to 20 km using the most permeable 2% portion of the landscape (Figure 13). The most permeable route follows the alkali desert scrub habitat out of the Carrizo Plain National Monument in the southern Target Zone and then heads in a northwesterly direction following the Carrizo Plain proper. About 5 km north of State Route 58 it starts to head almost due north and then appears to follow Bitterwater Valley Road east into the Shale Hills and then to the Antelope Valley beyond. Kit fox biologists concur that these results are much more biologically meaningful and reflect the most probable route for kit fox traveling between the northern and southern Target Zones.

Figure 10.
Landscape Permeability for Pronghorn antelope

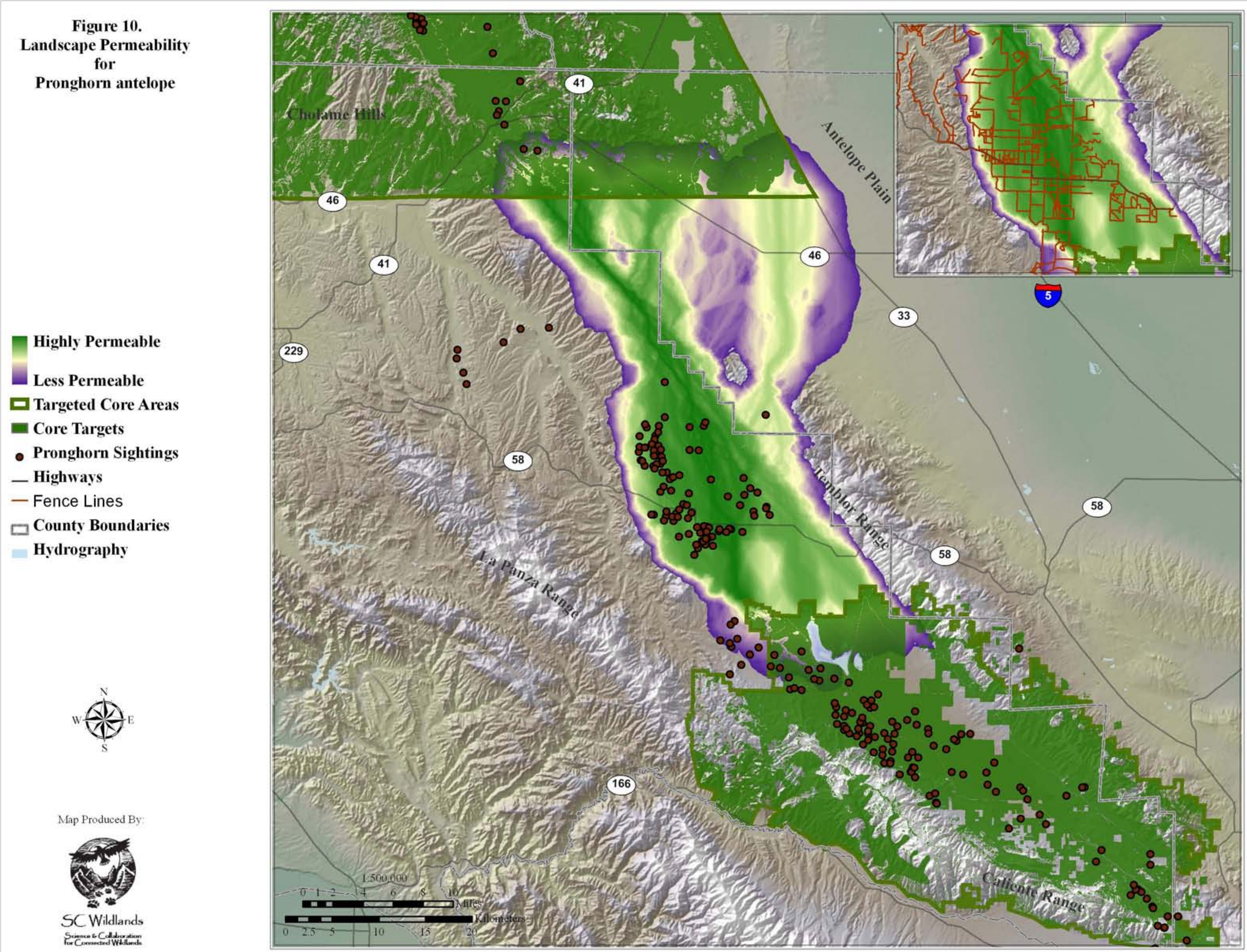
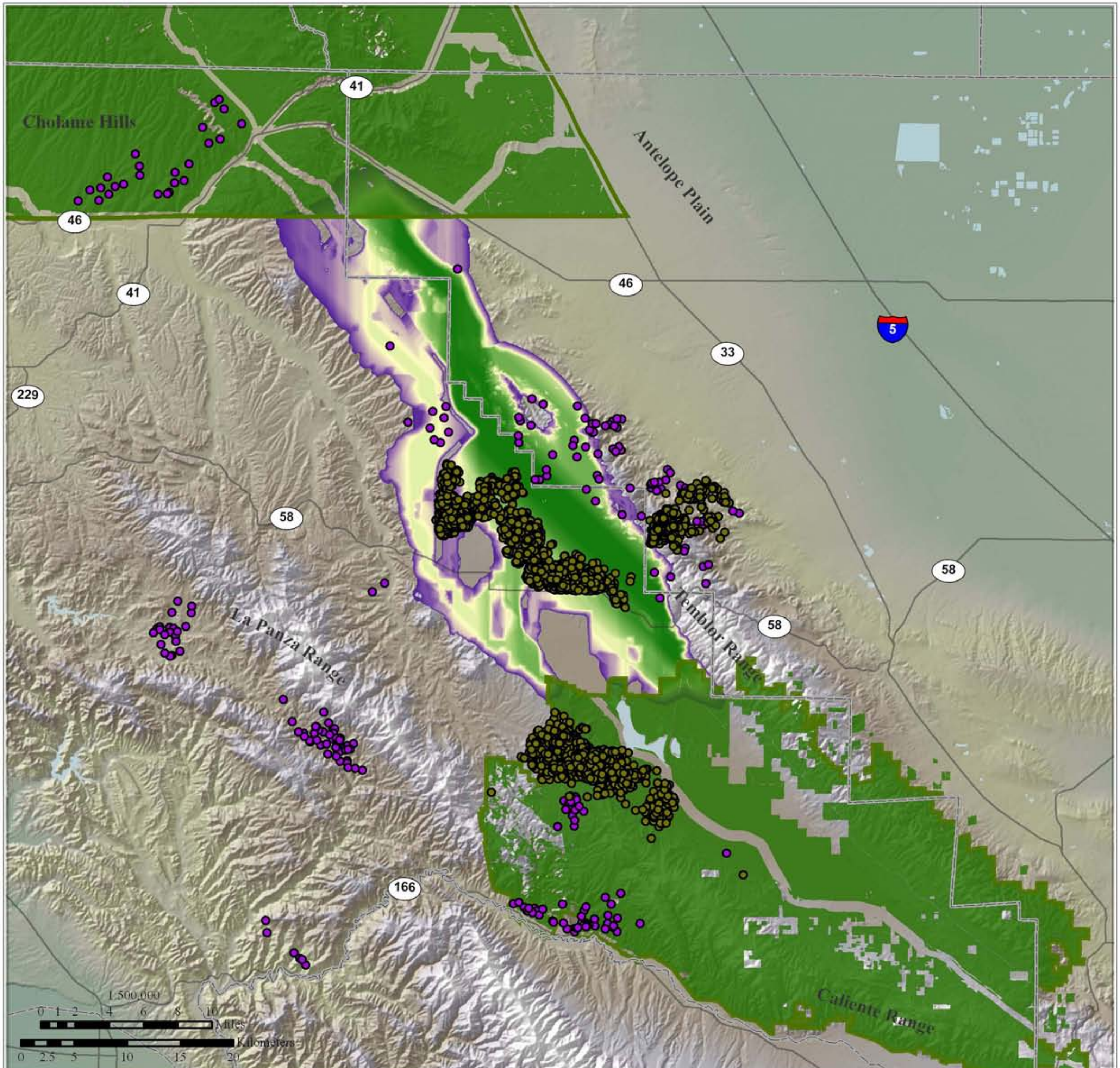


Figure 11.
Landscape Permeability
for
Tule elk



Highly Permeable
Less Permeable
Collared Sightings
Flight Sightings
Targeted Core Areas
Core Targets
Highways
County Boundaries
Hydrography

N
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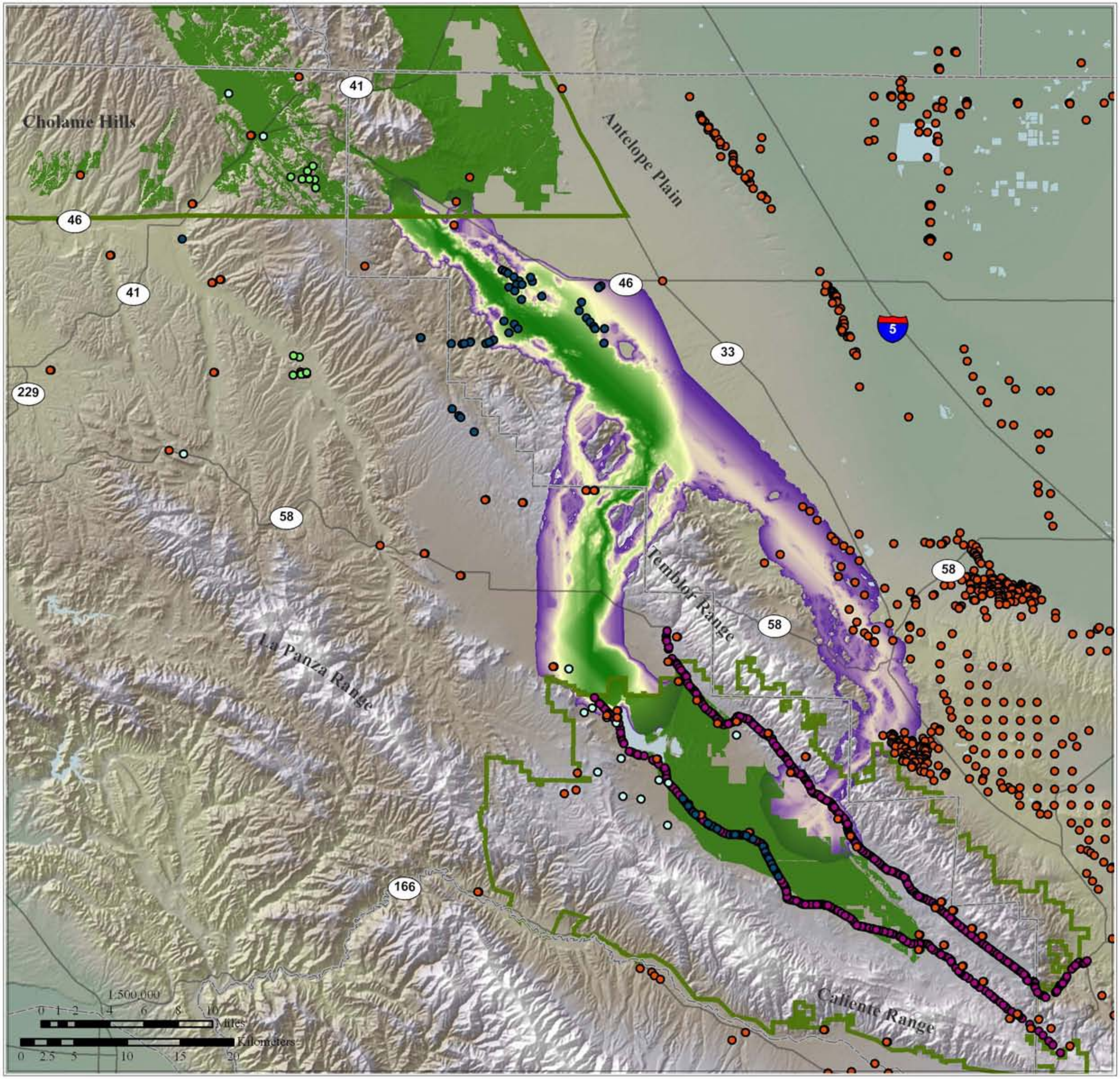
Map Produced By:

SC Wildlands
Science & Collaboration for Connected Wildlands

Figure 12.
Landscape Permeability for San Joaquin kit fox (based on suitability ratings)



- Highly Permeable
- Less Permeable
- Core Targets
- Targeted Core Areas
- Kit Fox Sightings
- ESRP Kit Fox Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB Kit Fox
- Highways
- County Boundaries
- Hydrography

Map Produced By:

SC Wildlands
Science & Collaboration for Connected Wildlands

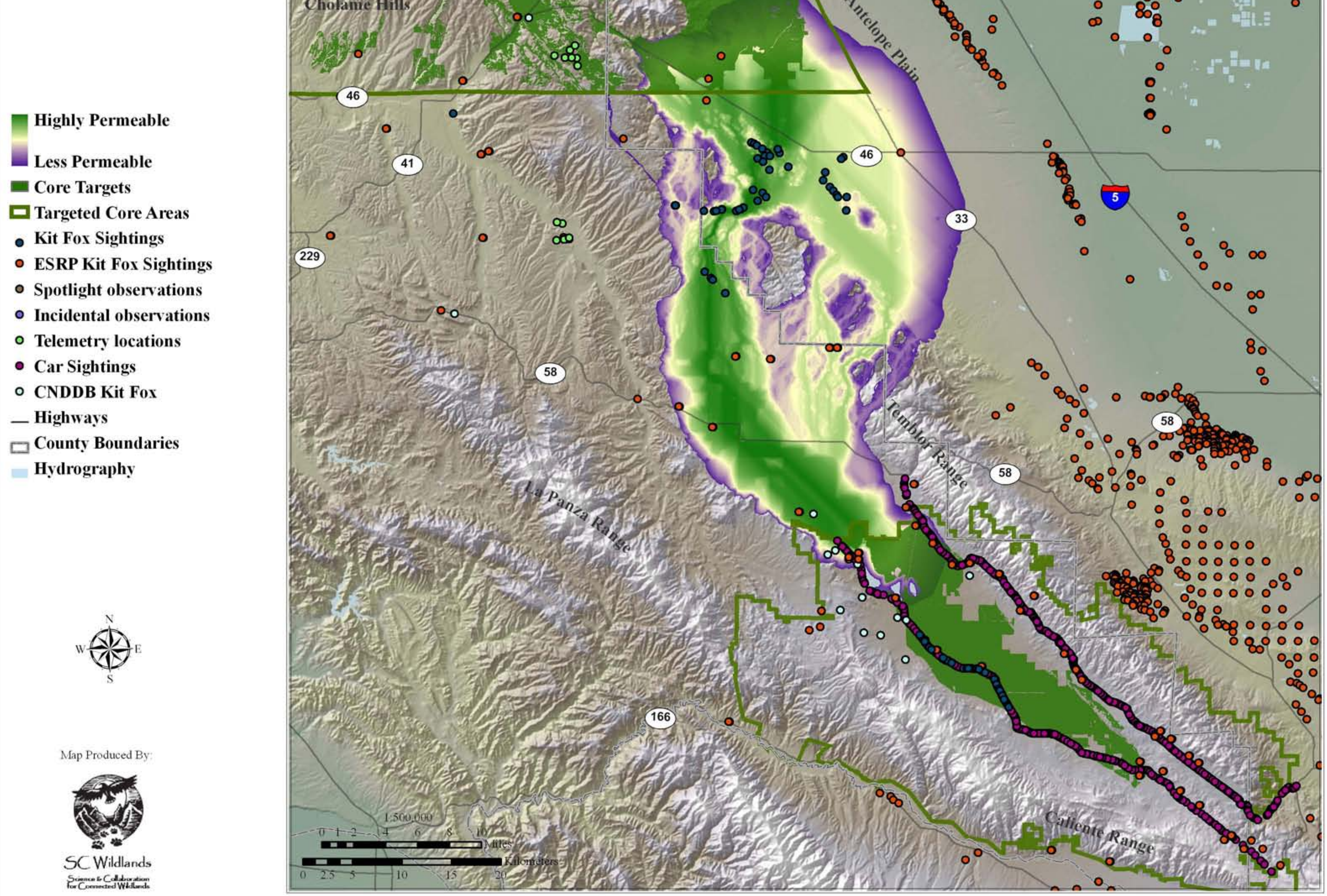


Figure 13. Landscape Permeability for San Joaquin kit fox (based on permeability ratings)

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Appendix A
Digital Data Sources Used

Name	Data Type	Scale	Date	Source
San Louis Obispo Vegetation	Polygon	1:100,000	1998	County of San Luis Obispo
CALVEG Vegetation	Polygon	1:24,000	1997, 2000, 2002	U.S. Forest Service
San Luis Obispo Crops	Polygon		2008	County of San Luis Obispo
Kern Crops	Polygon		2005	County of Kern
TIGER Roads	Line	1:100,000	2007	U.S. Bureau of the Census
California Highways	Line		2001	California Department of Transportation
National Elevation Dataset	Raster	10 meter	1999	U.S. Geological Survey
Conservation Lands (CPAD)	Polygon		2008	GreenInfo Network
Counties	Polygon	1:24,000	2004	California Department of Forestry and Fire Protection
Precipitation Normals	Raster	800 meters	1971-2000	PRISM Group, Oregon State University
National Hydrography Dataset	Line and Polygon	1:100,000	2007	U.S. Geological Survey
San Luis Obispo Aerial Photos			2007	San Luis Obispo County
Terrain Ruggedness	Raster	30 meter	2007	Endangered Species Recovery Program
Vegetation Density	Raster	30 meter	2001-2006	Endangered Species Recovery Program: Generated from Global Land Cover Facility MODIA Normalized Difference Vegetation Index [NDVI]

Tule Elk Model Inputs

Variable	Permeability	Suitability
Factor Weights (100%)		
Vegetation	50%	50%
Road Density	50%	50%
Vegetation		
Alkali Desert Scrub	6	0.4
Annual Grassland (Avena)	1	0.9
Annual Grassland (Brome)	4	0.6
Barren	9	0.1
Blue Oak-Foothill Pine	7	0.3
Blue Oak Woodland	6	0.4
Chamise-Redshank Chaparral	9	0.1
Closed-Cone Pine-Cypress	9	0.1
Coastal Oak Woodland	9	0.1
Coastal Scrub	4	0.6
Deciduous orchard	10	0
Desert Riparian	10	0
Desert Scrub	6	0.4
Desert Wash	10	0
Dryland Grain Crops	4	0.6
Eucalyptus	10	0
Evergreen orchard	10	0
Freshwater Emergent Wetland	2	0.8
Irrigated Grain Crops	2	0.8
Irrigated Hayfield	3	0.7
Irrigated Row and Field Crops	2	0.8
Juniper	4	0.6
Lacustrine	6	0.4
Mixed Chaparral	10	0
Montane Chaparral	9	0.1
Montane Hardwood	10	0
Montane Hardwood-Conifer	10	0
Orchard-Vineyard	8	0.2
Pasture (Irrigated)	1	0.9
Perennial Grassland	1	0.9
Pinyon-Juniper	10	0
Rice	n/a	n/a
Sagebrush	7	0.3
Sierran Mixed Conifer	10	0

Urban	10	0
Valley Foothill Riparian	5	0.5
Valley Oak Woodland	6	0.4
Vineyard	8	0.2
Wet Meadow	1	0.9
Road Density		
0 – 0.5 km/km^2	1	0.9
0.5 – 1 km/km^2	8	0.2
1 – 2 km/km^2	10	0
2 – 4 km/km^2	10	0
4 – 6 km/km^2	10	0
6 – 8 km/km^2	10	0
8 – 10 km/km^2	10	0
10 km/km^2 and above	10	0

Pronghorn Antelope Model Inputs

Variable	**Permeability**	**Suitability**
Factor Weights (100%)		
Vegetation	35%	35%
Road Density	10%	10%
Topography	55%	-
Slope	-	55%
Vegetation		
Alkali Desert Scrub	3	0.7
Annual Grassland (Avena)	1	0.9
Annual Grassland (Brome)	3	0.7
Barren	9	0.1
Blue Oak-Foothill Pine	7	0.3
Blue Oak Woodland	7	0.3
Chamise-Redshank Chaparral	9	0.1
Closed-Cone Pine-Cypress	9	0.1
Coastal Oak Woodland	9	0.1
Coastal Scrub	6	0.4
Deciduous orchard	10	0
Desert Riparian	10	0
Desert Scrub	3	0.7
Desert Wash	10	0
Dryland Grain Crops	2	0.8
Eucalyptus	10	0
Evergreen orchard	10	0
Freshwater Emergent Wetland	2	0.8
Irrigated Grain Crops	2	0.8
Irrigated Hayfield	1	0.9
Irrigated Row and Field Crops	2	0.8
Juniper	5	0.5

Lacustrine	6	0.4
Mixed Chaparral	10	0
Montane Chaparral	8	0.2
Montane Hardwood	10	0
Montane Hardwood-Conifer	10	0
Orchard-Vineyard	10	0
Pasture (Irrigated)	1	0.9
Perennial Grassland	1	0.9
Pinyon-Juniper	10	0
Rice	n/a	n/a
Sagebrush	3	0.7
Sierran Mixed Conifer	10	0
Urban	8	0.2
Valley Foothill Riparian	6	0.4
Valley Oak Woodland	7	0.3
Vineyard	10	0
Wet Meadow	1	0.9
Road Density		
0 – 0.5 km/km^2	1	0.9
0.5 – 1 km/km^2	2	0.8
1 – 2 km/km^2	2	0.8
2 – 4 km/km^2	6	0.4
4 – 6 km/km^2	7	0.3
6 – 8 km/km^2	8	0.2
8 – 10 km/km^2	9	0.1
10 km/km^2 and above	10	0
Topography		
Canyon bottoms	7	
Ridgetops	10	
Flats	1	
Slopes	4	
Slope		
0-5%		0.99
5-20%		0.66
>20%		0.33

Kit Fox Permeability and Suitability

Variable	**Permeability based on Permeability**	**Permeability based on Suitability**	**Suitability**
Factor Weights (100%)			
Vegetation	40%	40%	50%
Road Density	5%	5%	-
Terrain Ruggedness	50%	50%	25%
Vegetation Density	5%	5%	25%

Vegetation			
Alkali Desert Scrub	1	1	0.9
Annual Grassland (Avena)	4	5	0.5
Annual Grassland (Brome)	1	1	0.9
Barren	1	8	0.2
Blue Oak-Foothill Pine	10	10	0
Blue Oak Woodland	10	10	0
Chamise-Redshank Chaparral	10	10	0
Closed-Cone Pine-Cypress	10	10	0
Coastal Oak Woodland	8	8	0.2
Coastal Scrub	10	10	0
Deciduous orchard	3	9	0.1
Desert Riparian	9	10	0
Desert Scrub	1	1	0.9
Desert Wash	1	1	0.9
Dryland Grain Crops	1	9	0.1
Eucalyptus	10	10	0
Evergreen orchard	3	9	0.1
Freshwater Emergent Wetland	10	10	0
Irrigated Grain Crops	1	10	0
Irrigated Hayfield	2	10	0
Irrigated Row and Field Crops	1	10	0
Juniper	3	4	0.60
Lacustrine	10	10	0
Mixed Chaparral	10	10	0
Montane Chaparral	10	10	0
Montane Hardwood	10	10	0
Montane Hardwood-Conifer	10	10	0
Orchard-Vineyard	4	10	0
Pasture (Irrigated)	7	7	0.3
Perennial Grassland	1	5	0.5
Pinyon-Juniper	10	10	0
Rice	10	10	0
Sagebrush	10	10	0
Sierran Mixed Conifer	10	10	0
Urban	1	9	0.1
Valley Foothill Riparian	10	10	0
Valley Oak Woodland	8	8	0.2
Vineyard	4	10	0
Wet Meadow	10	10	0
Road Density			
0 – 0.5 km/km^2	1	1	
0.5 – 1 km/km^2	1	1	
1 – 2 km/km^2	1	1	
2 – 4 km/km^2	3	3	

4 – 6 km/km^2	3	3	
6 – 8 km/km^2	5	5	
8 – 10 km/km^2	8	8	
10 km/km^2 and above	10	10	
Terrain Ruggedness			
5	10	10	0.05
50	10	10	0.50
85	3	3	0.85
100	1	1	1.00
Vegetation Density			
0-9	10	10	0.00-0.09
10-19	9	9	0.10-0.19
20-29	8	8	0.20-0.29
30-39	7	7	0.30-0.39
40-49	6	6	0.40-0.49
50-59	5	5	0.50-0.59
60-69	4	4	0.60-0.69
70-79	3	3	0.70-0.79
80-89	2	2	0.80-0.89
90-99	1	1	0.90-0.99

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE STATE OF CALIFORNIA
1516 NINTH STREET, SACRAMENTO, CA 95814
1-800-822-6228 – WWW.ENERGY.CA.GOV

APPLICATION FOR CERTIFICATION FOR THE *CARRIZO ENERGY SOLAR FARM PROJECT*

Docket No. 07-AFC-8

PROOF OF SERVICE
(Revised 2/18/2009)

APPLICANT

Perry H. Fontana, QEP
Vice President-Projects
Ausra, Inc.
2585 East Bayshore Road
Palo Alto, California 94303
perry@ausra.com

APPLICANT CONSULTANT

Angela Leiba, GISP
Senior Project Manager
GIS Manager/Visual Resource Specialist
URS Corporation
1615 Murray Canyon Road, Suite 1000
San Diego, CA 92108
angela_leiba@urscorp.com

Kristen E. Walker, J.D.
URS Corporation
1615 Murray Canyon Road, Suite 1000
San Diego, California 92108
kristen_e_walker@urscorp.com

COUNSEL FOR APPLICANT

Jane E. Luckhardt
DOWNEY BRAND
621 Capitol Mall, 18th Floor
Sacramento, CA 95814
jluckhardt@downeybrand.com

INTERESTED AGENCIES

California ISO
e-recipient@caiso.com

INTERVENORS

*Mr. John A. Ruskovich
13084 Soda Lake Road
Santa Margarita, California 93453
agarnett@tcsn.com

*Mr. Michael Strobridge
9450 Pronghorn Plains Road
Santa Margarita, California 93453
mike_76@live.com

California Unions for Reliable Energy (CURE)
c/o Tanya Gulesserian
Adams Broadwell Joseph & Cardozo
601 Gateway Boulevard, Suite 1000
South San Francisco, CA 94080
tgulesserian@adamsbroadwell.com

John Burch
Traditional Council Lead
Salinan Tribe
8315 Morro Road, #202
Atascadero, California 93422
salinantribe@aol.com

*Environmental Center of San Luis Obispo (ECOSLO)
c/o Babak Naficy
P.O. Box 13728
San Luis Obispo, California 93406
babaknaficy@sbcglobal.net

ENERGY COMMISSION

JEFFREY D. BYRON
Commissioner and Associate Member
jbyron@energy.state.ca.us

Gary Fay
Hearing Officer
Gfay@energy.state.ca.us

John Kessler
Project Manager
jkessler@energy.state.ca.us

Caryn Holmes
Staff Counsel
cholmes@energy.state.ca.us

Michael Doughton
Staff Counsel
mdoughto@energy.state.ca.us

Elena Miller
Public Adviser
publicadviser@energy.state.ca.us

*indicates change

DECLARATION OF SERVICE

I, Hilarie Anderson, declare that on April 2, 2009, I served and filed copies of the attached Revised Draft Summary Report of Task 1 Modeling Results – Baseline Conditions. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at: **[http://www.energy.ca.gov/sitingcases/carrizo/index.html]**. The document has been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(C*heck all that Apply*)

For service to all other parties:

_x__sent electronically to all email addresses on the Proof of Service list;

_x__by personal delivery or by depositing in the United States mail at Sacramento, California with first-class postage thereon fully prepaid and addressed as provided on the Proof of Service list above to those addresses **NOT** marked "email preferred."

AND

For filing with the Energy Commission:

____sending an original paper copy and one electronic copy, mailed and emailed respectively, to the address below **(preferred method);**

OR

_____depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 07-AFC-8
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512

docket@energy.state.ca.us

I declare under penalty of perjury that the foregoing is true and correct.

Original Signature in Dockets
Hilarie Anderson

*indicates change