**DONALD BREN SCHOOL OF
ENVIRONMENTAL SCIENCE & MANAGEMENT**
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

Conservation Assessment for the Cuyama Valley: Current Conditions and Planning Scenarios

A 2009 Group Project Final Report
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Current Conditions and Planning Scenarios
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The mission of the Donald Bren School of Environmental Science and Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principle of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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FRANK DAVIS, PH.D.

EXECUTIVE SUMMARY

The Nature Conservancy (TNC) has identified the Cuyama Valley as a potential priority region due to its ecological richness, rare plant communities, and its potential to function as a wildlife corridor between the conserved lands of the Carrizo Plain National Monument and Los Padres National Forest. In this project, we assess the impact of current land use on the Cuyama Valley's riparian habitat, habitat connectivity, and groundwater resources. Additionally, we evaluate potential threats to habitat connectivity and water resources through four scenarios that depict our vision of how the valley may look by the year 2050.

Analysis of aerial photographs reveals a significant loss of historically present riparian habitat concurrent with the expansion of agriculture and the decline of the groundwater table. Measurement of eighteen transects along the Cuyama River revealed a decline in riparian vegetation, river channel width, and channel complexity since the first available aerial photograph of the region in 1938.

Habitat connectivity for four representative species, Blunt-nosed leopard lizard (*Gambelia sila*), Two-striped gartersnake (*Thamnophis hammondii*), Pronghorn antelope (*Antilocapra americana*) and San Joaquin kit fox (*Vulpes macrotis mutica*), is strong throughout the valley despite the decline of historic riparian habitat and intensive agriculture. Our results also indicate that habitat connectivity in every modeled scenario improves over current conditions.

Development of a regional hydrologic budget provides evidence that current land use practices are not sustainable with respect to groundwater resources. In some parts of the valley, declines in the water table exceed 300 feet since the introduction of irrigated agriculture. If the rate of groundwater extraction continues, we estimate that the total available storage will deplete in approximately fifty years. However, our scenario planning analysis illustrates that major shifts in agriculture and residential development of the valley are possible with groundwater extraction limited to the rate of natural recharge. To preserve the economic and ecological viability of the valley, future land use should be tied to sustainable groundwater use.

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INTRODUCTION

The Nature Conservancy (TNC) of California has identified the Cuyama River Valley and Sierra Madre Foothills (herein Cuyama Valley, Figure 3) as a potential conservation priority area (The Nature Conservancy 2006). The area harbors rich ecological diversity and rare species that are found in few other places in California. The Valley may also facilitate wildlife movement and promote genetic connectivity between the conserved lands of the Carrizo Plain National Monument and Los Padres National Forest.

Current land use practices in the Cuyama Valley consist primarily of irrigated agriculture, dry farming, ranching, rural residential development, gravel mining operations, and petroleum production. On average, the area receives less than ten inches of rain annually and faces serious hydrologic impacts as a result of low annual rainfall, high evapotranspiration rates, and intensive pumping for agriculture. The region may develop further over the next ten years, fueling changes in the dominant agricultural practices and residential infrastructure, which may alter the human demand for water. These disruptions could interfere with wildlife movement and further imperil rare and sensitive species and ecologic communities.

The magnitude of the threat posed by economic development or shifts in agricultural land use is unknown. This project assesses current and potential future impacts of human land use on habitat connectivity and groundwater resources. Additionally, changes in woody riparian vegetation over the last eighty years were quantified. It is anticipated that the results of the project will provide tools and knowledge to help inform conservation planning in the region.

CONCEPTUAL FRAMEWORK

A conceptual framework helps conceptualize the planning process and allows better integration of varied disciplines (Knight et al. 2006). Our project applies Carl Steinitz' "Framework Model for Landscape Planning" which provides a "robust and flexible process for assessing a landscape…that is suited to address multiple [abiotic, biotic, and cultural] goals, and is adaptable to any strategic planning context" (Ahern 2006, p. 126). The framework poses six questions to guide a comprehensive assessment of the landscape, and the processes that drive the landscape (Figure 1 below).

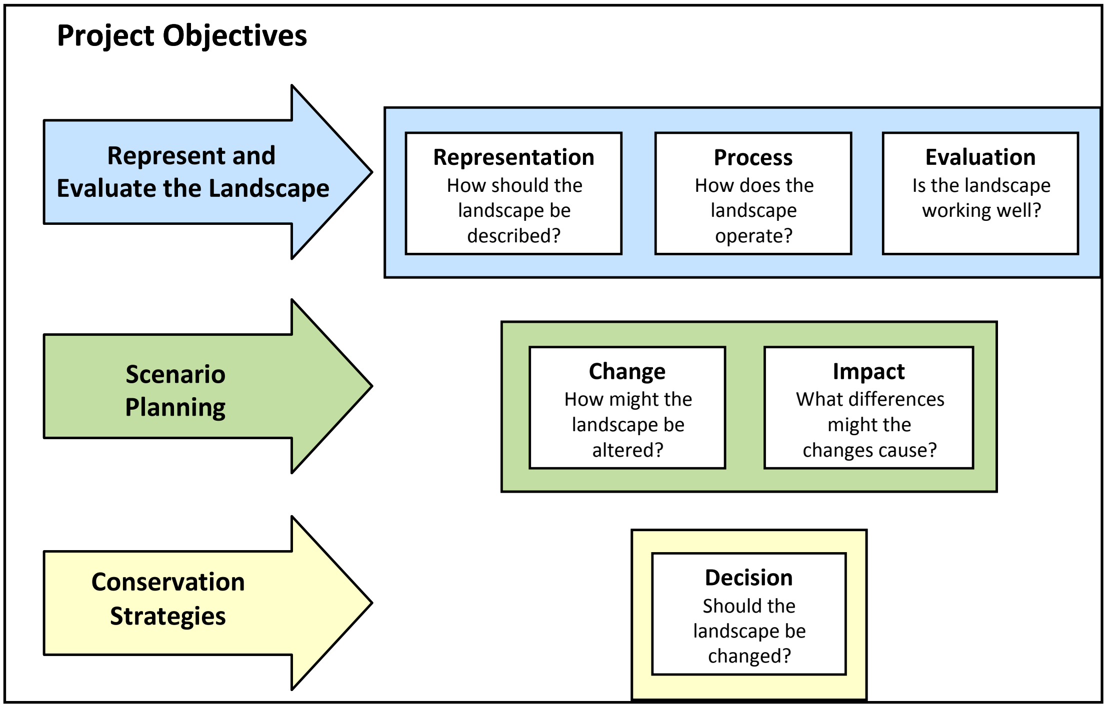


Figure 1: Conceptual framework used as a project guide. Model was adapted from Steinitz as cited in Ahern (2006).

Represent and Evaluate the Landscape

Following the conceptual framework described above, the project will identify and evaluate how abiotic, biotic, and social processes interact to influence the landscape of the Cuyama Valley. To assess the landscape processes, the project will (1) develop a water budget based on rates of natural recharge and human extraction, (2) understand and quantify the economic and social processes, and (3) assess the impact of current land use on habitat distribution and connectivity.

Scenario Planning (Landscape Change Models)

Threats to the wildlife corridor function and hydrology will be evaluated through four future development scenarios for the region. Specifically, the project will explore how changes in residential development, land use, and industry, will affect the availability of water and conservation targets.

Conclusions and Recommendations (Decision Models)

Results from the project will provide tools and knowledge to inform conservation planning in the region.

REPRESENT AND EVALUATE THE LANDSCAPE

Geology

The Cuyama Valley was formed by a down faulted block that is bordered on the north by the Morales and Whiterock faults and on the south by the South Cuyama and Ozena faults (Singer & Swarzenski 1970). The basin has been filled with continental deposits resulting from the active faults that border the valley to the north and south, and by alluvium deposited by Cuyama River. These deposits coupled with the semi-arid climate of the region have created a wide distribution of soil (loam) types with varying compositions of sand, silt, and clay (Figure 2). Older continental deposits and underlying formations in some of parts of the valley have been folded into a large syncline, which dips northwest toward the valley plain (Upson & Worts 1951). The older deposits have little effect on the distribution and subterranean topography of the groundwater basin, however, the alluvial formations have been folded so that the slope of the beds is favorable for the transmission of water from the southeastern part of the valley (Upson & Worts 1951).

Aside from the major faults that bound the valley to the north and south, the only faults known to affect the movement of groundwater are two associated with the Graveyard and Turkey Trap ridges that occur in the middle of the valley (Upson & Worts 1951). These faults have uplifted semi-permeable deposits in the north and restrain movement of groundwater percolating through younger permeable deposits from the south and southeast, thus forcing water to the surface (Upson & Worts 1951). Natural springs have been historically noted near the towns of Cuyama and New Cuyama but were reported dry by 1970 (Singer & Swarzenski 1970).

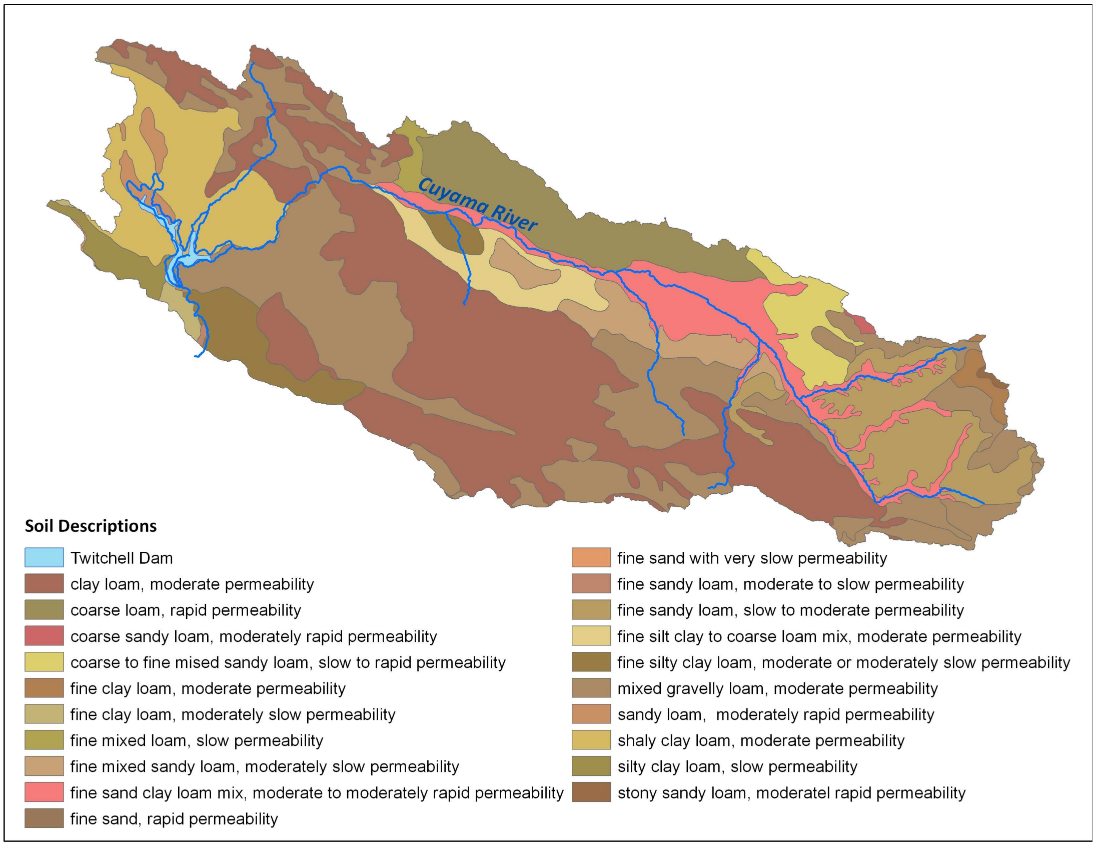


Figure 2: Geologic formations found within the Cuyama Valley.

Climate

The climate of the Cuyama Valley is typical of semi-arid valleys of California's central coast, with average monthly temperatures ranging from 75°F in summer to 40°F in winter months. Average annual precipitation is less than six inches and occurs primarily in winter and early spring, peaking in February. Annual rainfall within the basin ranges from six inches at the valley floor to twenty-four inches in the peaks of the Sierra Madre Mountains that form the southeastern boundary of the watershed (County of Santa Barbara Water Resources 1992).

Vegetation and Wildlife

Situated on the boundary between Santa Barbara and San Luis Obispo Counties, the Cuyama Valley is a region of exceptional ecological diversity (The Nature Conservancy 2006). Annual grasslands, chaparral and scrub habitats, blue oak woodlands and pinyon-juniper woodlands dominate the area, but rare habitats such as saltbush scrub, alkaline marshes, and riparian forests are also present. Many bird, herptile, and mammal species inhabit the region. Species of note range from the Tule elk (*Cervus elaphus nannodes*) and the Burrowing owl *(Athene cunicularia*), to smaller species like the California horned lizard (*Phrynosoma coronatum frontale*) and the Western spadefoot toad (*Spea hammondii*). Federally listed and endangered species in the area include the Giant kangaroo rat (*Dipodomys ingens*), San Joaquin kit fox (*Vulpes macrotis mutica*), and Blunt-nosed leopard lizard (*Gambelia sila*) (The Nature Conservancy 2008). Additionally, a number of plant and animal species have been identified as important conservation targets as shown in Table 1 (The Nature Conservancy 2006).

Table 1: TNC Conservation Interests in the Cuyama Valley.

Taxa	**Common Name**	**Scientific Name**
Birds	Tricolored blackbird	*Agelaius tricolor*
Herpetiles	Blunt-nosed leopard lizard	*Gambelia sila*
Herpetiles	Two-striped gartersnake	*Thamnophis hammondii*
Mammals	Giant kangaroo rat	*Dipodomys ingens*
Mammals	San Joaquin antelope squirrel	*Ammospermophilus nelsoni*
Mammals	San Joaquin kit fox	*Vulpes macrotis mutica*
Mammals	Tulare grasshopper mouse	*Onychomys torridus tularensis*
Plants	California jewel-flower	*Caulanthus californicus*
Plants	Jared's pepper-grass	*Lepidium jaredii ssp. Jaredii*
Plants	Lemmon's jewel-flower	*Caulanthus coulteri var. lemm*
Plants	Pale-yellow layia	*Layia heterotricha*
Plants	Recurved larkspur	*Delphinium recurvatum*
Plants	Showy madia	*Madia radiate*
Plants	Woven-spored lichen	*Texosporium sancti-jacobi*
Vegetation Community	Alkali marsh	
Vegetation Community	Alluvial fan sage scrub	
Vegetation Community	Annual grassland	
Vegetation Community	Blue oak forest / woodland	
Vegetation Community	Canyon live oak forest	
Vegetation Community	Central Coast riparian forests	
Vegetation Community	Chamise chaparral	
Vegetation Community	Coast live oak forest / woodland	
Vegetation Community	Coastal sage scrub	
Vegetation Community	Juniper woodland and scrub / Cismontane juniper woodland and scrub	
Vegetation Community	Mixed chaparral	
Vegetation Community	Mixed montane chaparral	
Vegetation Community	Mojavean pinyon and juniper woodlands	
Vegetation Community	Permanent freshwater marsh	
Vegetation Community	Saltbrush scrub	
Vegetation Community	Semi-desert chaparral	
Vegetation Community	Semi-desert scrub / Desert scrub	
Vegetation Community	Sycamore alluvial woodland	

Socioeconomic Setting

The Cuyama Valley lies 35 miles north of the city of Santa Barbara in the southern part of the Coast Ranges of California. The valley lies within four county jurisdictions: Santa Barbara, San Luis Obispo, Kern, and Ventura (Figure 3). The region is an unincorporated rural area with a very low population density. There are roughly 1,350 permanent inhabitants in the Cuyama Housing Management Area, encompassing the small towns of Cuyama and New Cuyama (County of Santa Barbara Office of Long Range Planning 2006). Although the area experienced an 11.9% growth rate between the years of 1990 and 2000, this translates into a net gain of only 150 residents. Furthermore, growth estimates from the Santa Barbara County Association of Governments project only 3% growth in the region over the next ten years. This represents the lowest growth projection of any planning region in the county (County of Santa Barbara Office of Long Range Planning 2006). Despite this, there is speculation that the rapid growth in the city of Santa Maria may generate additional housing demand in the Cuyama Valley. An increased demand for housing in the region may, in turn, shift patterns of land use, residential infrastructure and residential water demand (Maloney 2008a). The effects of such accelerated development are analyzed in the Scenario Planning section of this report.

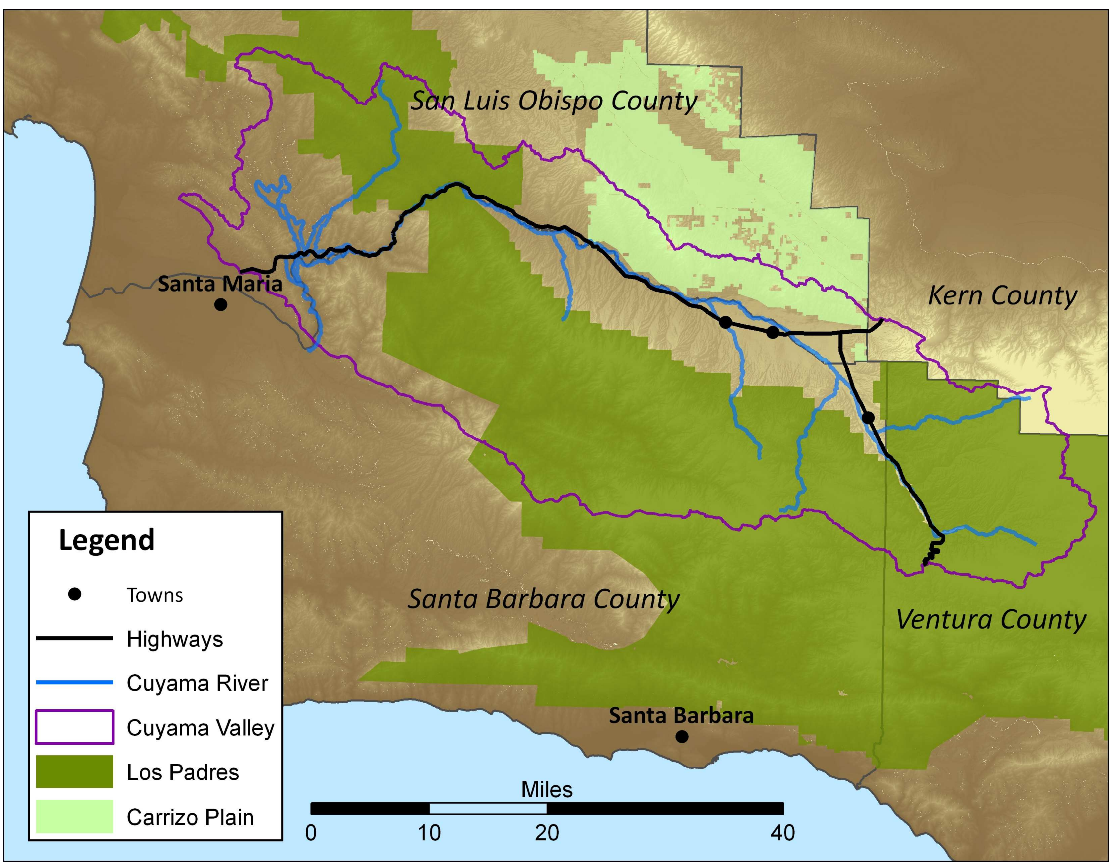


Figure 3: Location of the Cuyama Valley in the Central Coast of California.

Land Management and Ownership

The distribution of land ownership in the Cuyama region is characterized by a distinctive wedge of private land surrounded by large areas of public land (Figure 4). Carrizo Plain National Monument and Los Padres National Forest are public lands managed by the Bureau of the Land Management and the US Forest Service, respectively. Additionally, California Department of Fish and Game manages the Carrizo Plain Ecological Reserve and the US Fish and Wildlife Service manages the Bitter Creek National Wildlife Refuge (Figure 4). The land managed by these four agencies comprise about fifty percent of our study area. Private land holdings generally occupy the flatlands that surround the river valley and include private ranches, farms, and other small businesses.

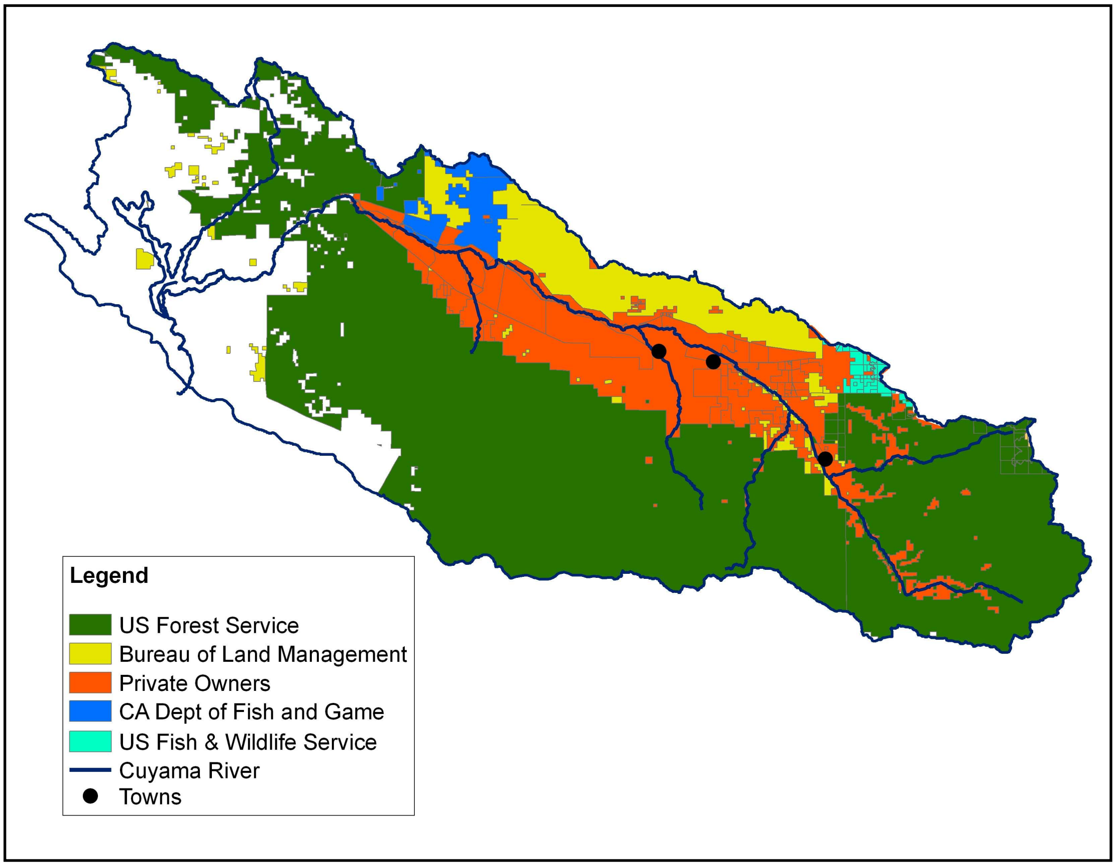


Figure 4: Land ownership in the Cuyama Valley.

Agriculture and Ranching

Irrigated agriculture is the dominant land use in the Cuyama Valley, with 20,000-25,000 acres devoted to active farming in any given year. Current agriculture consists primarily of row crops rotated between root vegetables, alfalfa, and grains.

The largest crop by acreage is carrots, with an estimated 6,000 acres cultivated in 2008 (Figure 5). This represents approximately 17 percent of the statewide carrot production (Vegetable Research and Information Center 1997). Rotational fields are almost exclusively irrigated with overhead or center pivot sprinkler systems. Vineyards and orchards (pistachio, peach, and quince), totaling 400 acres, are irrigated with drip and micro-sprinkler irrigation systems and are mostly located near the town of Ventucopa, southeast of the primary agricultural zone. The estimated total acreage of crops grown in the Cuyama Valley during the sampling years of 1977, 1985, 1996 and 2008 are presented in Table 2. Figures for total water requirements of major crop classes (Table 3) were obtained from irrigation surveys conducted by San Luis Obispo County (San Luis Obispo County Water Resources 1998).

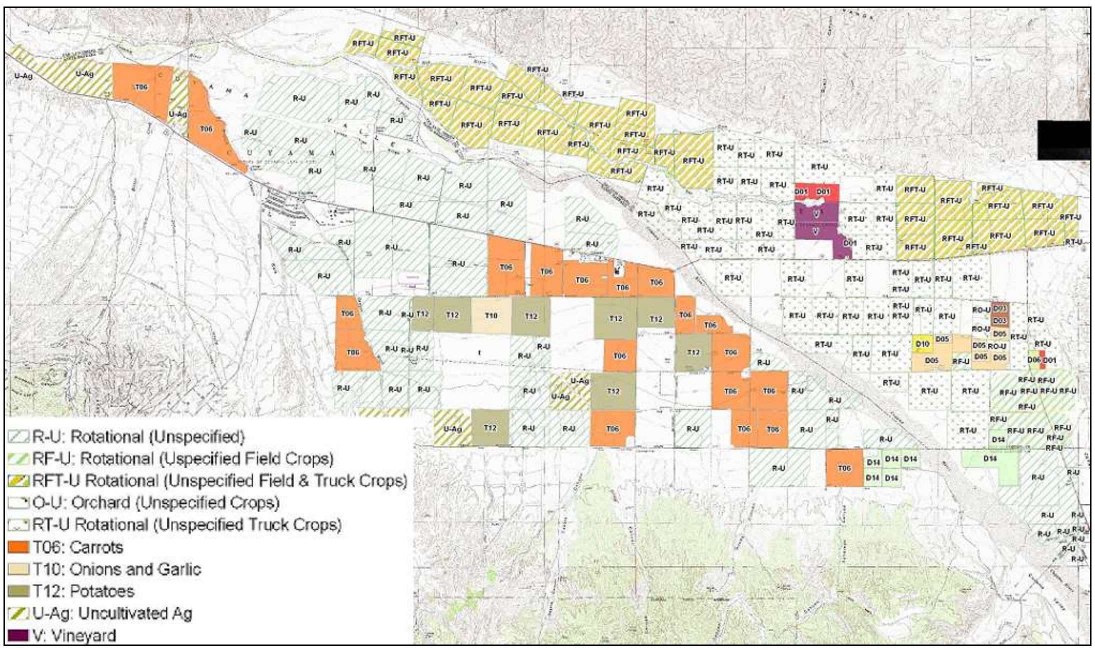


Figure 5: Current distribution of agricultural crops in the Cuyama Valley.

Historic crop acreages were determined through Geographic Information Systems (GIS) analysis of the California Department of Water Resources Land Use series published in 1977, 1985 and 1996. Maps of all years in the series appear in Appendix C. Land use and crop classification data was available for areas that match with US Geological Survey (USGS) Quads 57-39 and 57-40. Since 1977, Cuyama has experienced three distinct phases in the predominant agricultural activity. Alfalfa was by far the largest crop by acreage in 1977 (Table 2). 1985 saw a transition from alfalfa to grain production, as well as the emergence of root vegetables. By 1996 much of the prime cropland surrounding the river was converted to apple orchards, carrots, and wheat. The current predominance of carrots and other root vegetables in rotation with grains and alfalfa took hold after the introduction of Asian apples in the

US market, which rendered Cuyama apple production economically unviable (Mercer 2009).

Table 2: Historic Cuyama Crop Acreages

Year	Carrots	Vegetables	Alfalfa	Orchard	Pistachio	Grains	Vineyard	Fallow
1977	926	70	13,627	4	0	3,745	0	2,696
1985	2,077	554	6,223	19	18	3,557	19	7,588
1996	4,469	1,899	2,137	2,918	229	5,569	37	2,838
2008*	6,000	4,000	3,000	600	400	5,000	220	4,000

* Due to ambiguous San Luis Obispo County pesticide classification of rotational crops, 2008 acreage figures are estimates based on historic trends and current agricultural production literature.

Table 3: Water requirements of crops grown in Cuyama Valley (San Luis Obispo County Water Resources 1998)

	Water Requirements (AF/Y)
Carrots	3
Vegetables	2.8
Alfalfa	5
Orchard	3.8
Pistachio	3.3
Vineyard	2.8
Grain	1.5

Rural Residential Development

Rural residential development consists of less than 200 farmsteads scattered across the privately owned portions of the valley. The vast majority of privately owned land in the valley is assigned an agricultural land use classification, which limits the density of residential structures to one primary residence per 20 acres of irrigated land in San Luis Obispo County (San Luis Obispo County Planning and Building 2009) and a maximum of 1 residence per 40 acres of agricultural land in Santa Barbara County (County of Santa Barbara Planning and Development 2008). Although scattered portions of the study area allow for settlements at this rate, much of the area in Santa Barbara County is zoned for one primary structure per 100 acres of farmed land. Zoning ordinance in both counties allows for the construction of one accessory residential structure for every primary residence.

Mining and Petroleum

Gravel, Sand and Gypsum Mining

Gravel, sand and gypsum from alluvial deposits have proven to be a valuable resource for construction. Three mines (GPS Mine, Lima Gypsum Mine, and Ozena Mine) are located on the upper Cuyama River in an area known to contain a high density of sensitive or endangered species. A fourth mine, operated by the Alamo Rock Company, is located north of Twitchell Dam on Alamo Creek (Figure 6). Plans for a fifth mine, the Diamond Rock Mine, are in progress (County of Santa Barbara Planning and Development 2007).

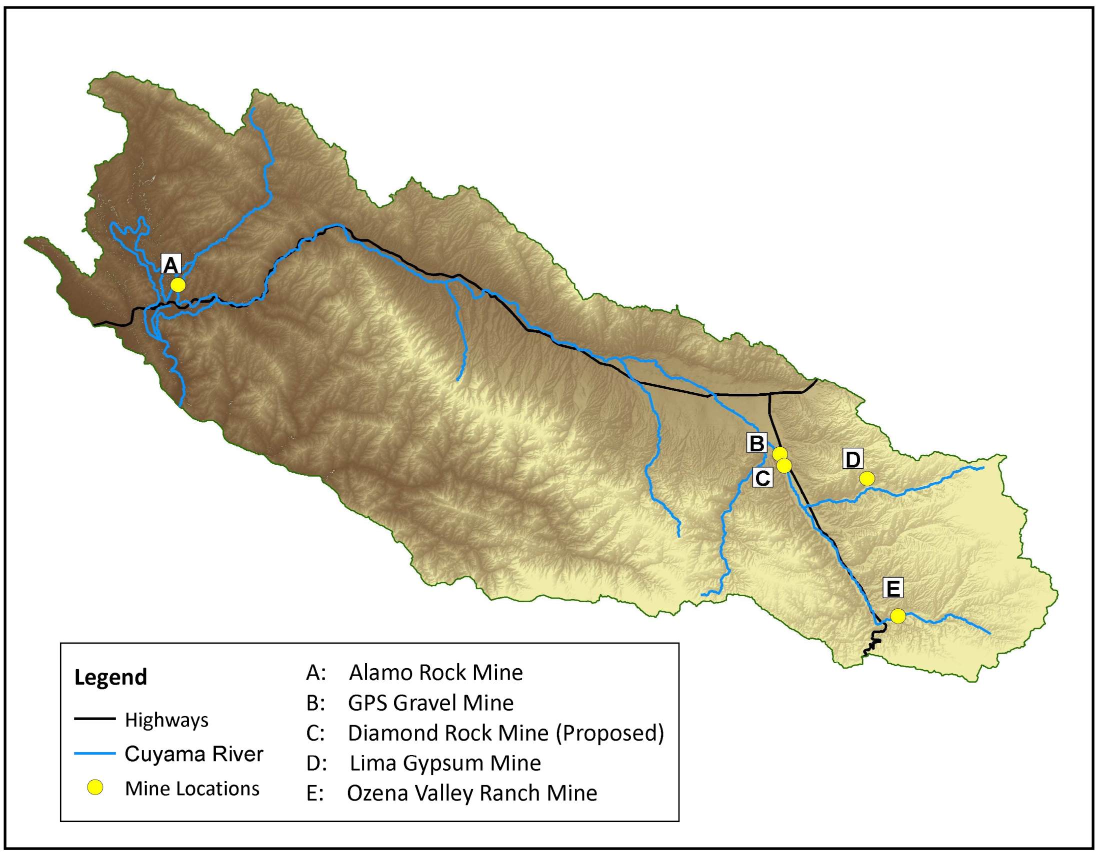


Figure 6: Location of the five active gravel mine operations in the Cuyama Valley.

In-stream gravel and sand mining changes the sediment of the river bed, destroys habitat for species that utilize the river, and may result in fragmentation of the riparian corridor. An aerial photograph of in-stream mining illustrates fragmentation of the river channel and riparian zone (Figure 7). The recovery time of mined stream systems in arid environments is expected to exceed 20 years (Langer 2003). The removal of aggregate from the river bed may also cause regional and localized geomorphic and hydrologic impacts to the area including increased total dissolved solid (TDS) levels in the groundwater and drawdown of the groundwater basin (County of Santa Barbara Planning and Development 2007). Aggregate mining in the Cuyama Valley used an estimated 1,120 acre-feet/year in 1995 (US Department of the Interior US Geological Survey 1995). The current combined water consumption of all Cuyama mining activities is unknown. In addition to the direct loss of habitat and alterations to the sediment balance, increased truck traffic and nighttime lighting may also significantly impact species (County of Santa Barbara Planning and Development 2007).

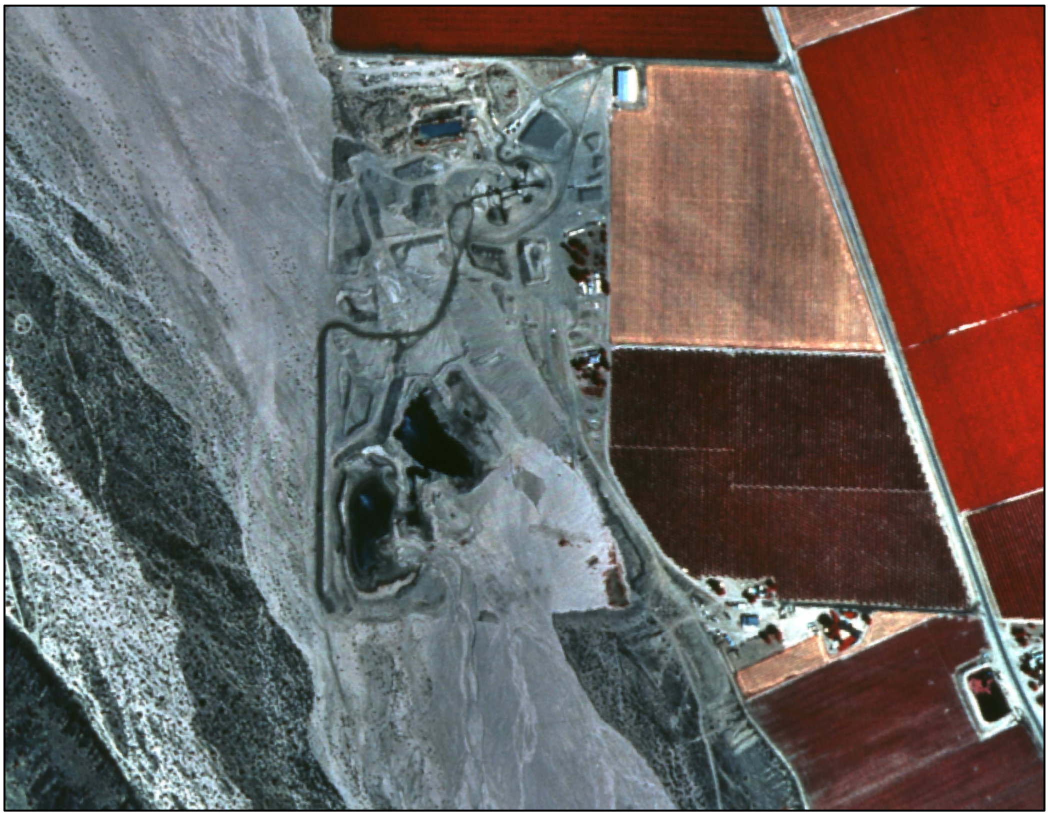


Figure 7: 2002 Aerial image of in-stream mining of aggregate in the Cuyama River.

The Diamond Rock Mine is a proposed sand and gravel mine to be located along the Cuyama River near the GPS Mine in Santa Barbara County. An Environmental Impact Report (EIR) of the proposed mine was completed in 2007. According to the EIR, the proposed Diamond Rock Mine will result in 27 acres of alluvial scrub habitat fragmentation in the riparian corridor, potentially impacting the following species: Blunt-nosed leopard lizard, San Joaquin kit fox, Loggerhead shrike (*Lanius ludovicianus*), and Lawrence's goldfinch (*Caduelis lawrencei*) (County of Santa Barbara Planning and Development 2007). Additionally, the Ozena Valley Ranch Mining Company has proposed a fifteen-acre expansion to the existing mining operations (Clerici 2007).

The 1989 California Geological Survey's mineral land classification of Santa Barbara and San Luis Obispo Counties classified only the western portion of the study area near Twitchell Dam where the Alamo Rock Company is located. This mine site is classified as likely to contain significant mineral deposits. According to personal correspondence in January 2009 with John Clikenbeard of the California Geological Survey, an update of the aggregate classification maps that will include the entire Cuyama region is currently in progress. An increase in aggregate mining activity could occur if the updated report indicates significant unexploited aggregate deposits in the area.

Petroleum Development

The Atlantic Richfield Oil Company began oil production in the early 1950s, with production peaking prior to 1977 (Cuyama Community Services District & Cuyama Valley Recreation District 2005). Currently, there are three oil fields located in the Cuyama Basin (Morales Canyon, Russell Ranch, and South Cuyama) (Figure 8).

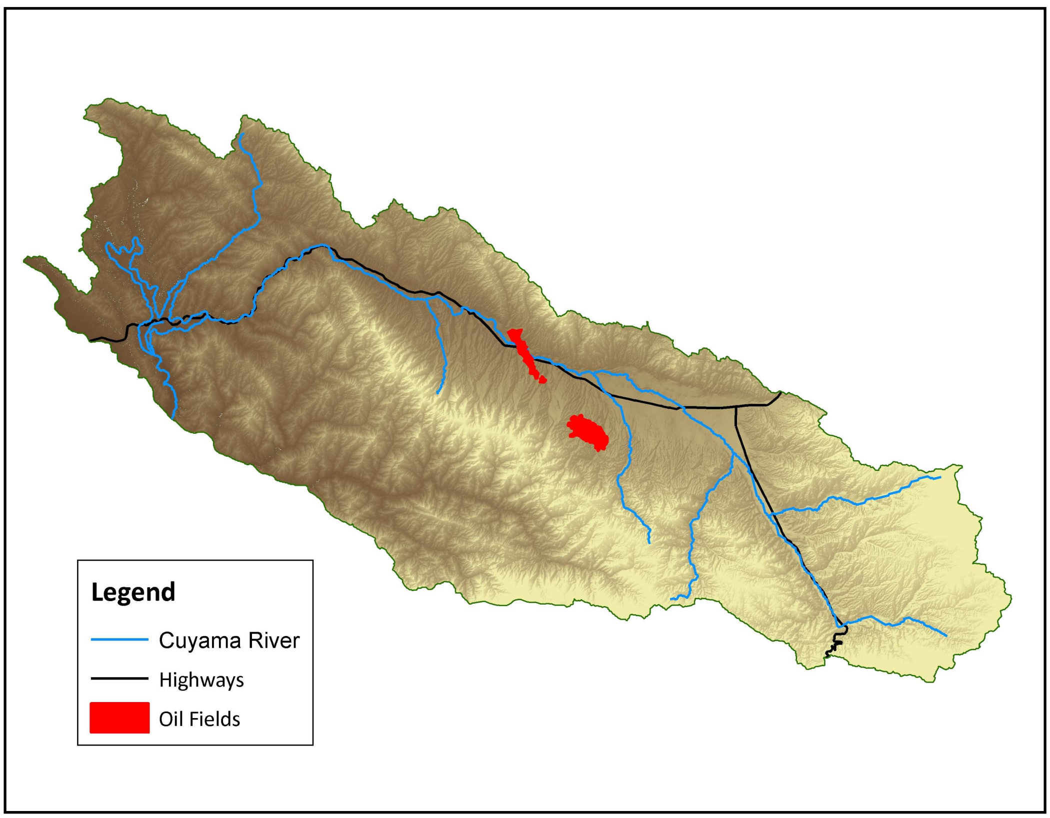


Figure 8: Location of oil fields in the Cuyama Valley.

Sections of the Los Padres National Forest lie within the Cuyama Valley and adjoin it. The Los Padres National Forest is the only California national forest with commercially developed oil and gas operations. The leasing of land and construction of roads within the National Forest for oil or gas exploration is determined by National Forest management, and is constrained by the Oil and Gas Environmental Impact Statement (US Forest Service 2005a). A 2005 Final Environmental Impact Statement indicated that an 80,258 acre area within the Los Padres National Forest, south of the current oil fields, is a High Oil and Gas Potential Area (HOGPA). This area, known as South Cuyama, may be made available for oil and gas exploration. Should the South Cuyama HOGPA be developed, potential impacts to species and habitat could occur (US Forest Service 2005b)

In 2006, the US Bureau of Land management announced its decision to auction off 34 parcels in Kern, Ventura, Santa Barbara, and San Luis Obispo counties for oil exploration and development as part of its quarterly oil and gas lease sales (US Department of the Interior Bureau of Land Management 2006). Nine of those parcels (Figure 9, Table 4: Parcels proposed for auction with critical habitat.) are located in the valley and provide habitat for several endangered plants and animals, including the San Joaquin kit fox and the California jewel flower (*Caulanthus californicus*) (US Department of the Interior Bureau of Land Management 2006). Although lessees would be subject to regulations aimed to protect endangered species (US Department of the Interior Bureau of Land Management 2006), the exploration and development of oil has the potential to reduce critical wildlife habitat.

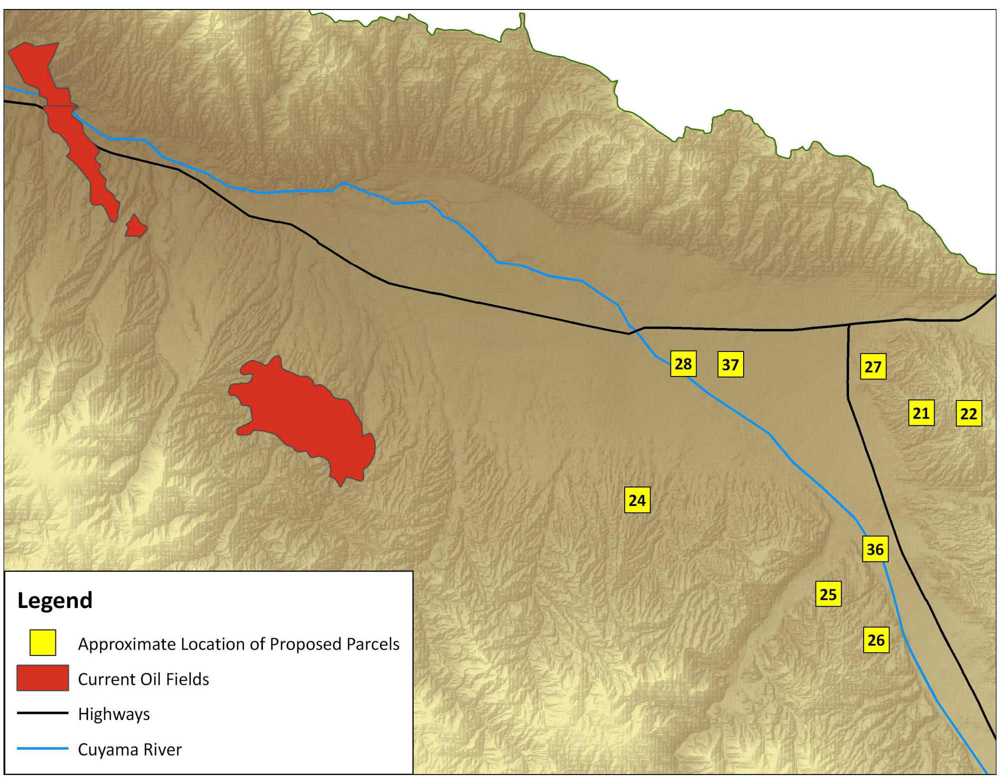


Figure 9: Approximate locations of the nine parcels proposed for oil auction in the Cuyama Valley based on location data provided by the Bureau of Land Management (2006).

Table 4: Parcels proposed for auction with critical habitat.

Parcel Number	**Area (acres)**
21	1087
22	1800
24	1605
25	2400
26	160.0
27	240.0
28	840.0
36	80.00
37	80.00
Total:	**8292**

Renewable Energy Development

A California Energy Resource map created in 2004 depicts a portion of the Cuyama Valley as suitable for concentrated thermal solar development (Black & Veatch Corporation 2008). Additionally, the Renewable Energy Transmission Initiative (RETI) Phase 1B planning document designates large portions of the study area as a potential Concentrated Renewable Energy Zone (CREZ) capable of generating 707 megawatts of thermal solar energy. It is important to distinguish the proposed solar generation site in the Cuyama Valley from the "Cuyama" CREZ, which lies in the Carrizo Plain north of the study area. The solar generating facility in the Cuyama Valley is named "Santa Barbara NE" and is intended to supplement large wind power installations in Los Padres National Forest and on the south coast near Gaviota. Specific locations for the solar thermal generation facility and associated transmission infrastructure other than a rough diagram (Figure 10) are unavailable at this time.

Figure 10: Proposed renewable energy resource development sites in Santa Barbara and San Luis Obispo Counties. Yellow squares are solar thermal generating facilities, purple polygons are wind generation sites and the green circle indicates a biomass project. Light grey regions define CREZ locations identified in the RETI resource assessment.

Hydrology and Water Use

The Cuyama Groundwater basin (Figure 11) encompasses 230 square miles and supports all land use in the valley (County of Santa Barbara Water Resources 1992). The Cuyama River is the principal source of recharge for the basin (California Department of Water Resources 2003a) and flows only a short distance below Ozena throughout the year (Upson & Worts 1951). However, during winter storms, flows may reach the State Highway 166 bridge near the town of Cuyama, roughly 25 miles from the river's headwaters. The river only completes the whole length of its course to Twitchell Dam following rare winter flood events (Upson & Worts 1951).

In general, groundwater recharge is roughly proportional to the amount of rainfall. Thus, the bulk of recharge in the basin occurs during and after storm events (Upson & Worts 1951). Exact figures for recharge of the groundwater basin are unavailable, but studies have estimated average yearly recharge to be anywhere between 8,000 acre-feet (County of Santa Barbara Water Resources 1992) and 13,000 acre-feet (Singer & Swarzenski 1970). These recharge estimates are based on the amount and distribution of rain, gauging station information from the Cuyama River, and other factors affecting infiltration, such as type of vegetation and soil moisture content. Unfortunately, much of this information is limited and incomplete (Appendix A).

The roughly 23,000 acres of irrigated agriculture and ranching rely exclusively on groundwater resources. Significant groundwater withdrawal for agriculture began in 1938 and has progressively increased since that time. Over 95% of groundwater use is applied towards agriculture (County of Santa Barbara Water Resources 1992).

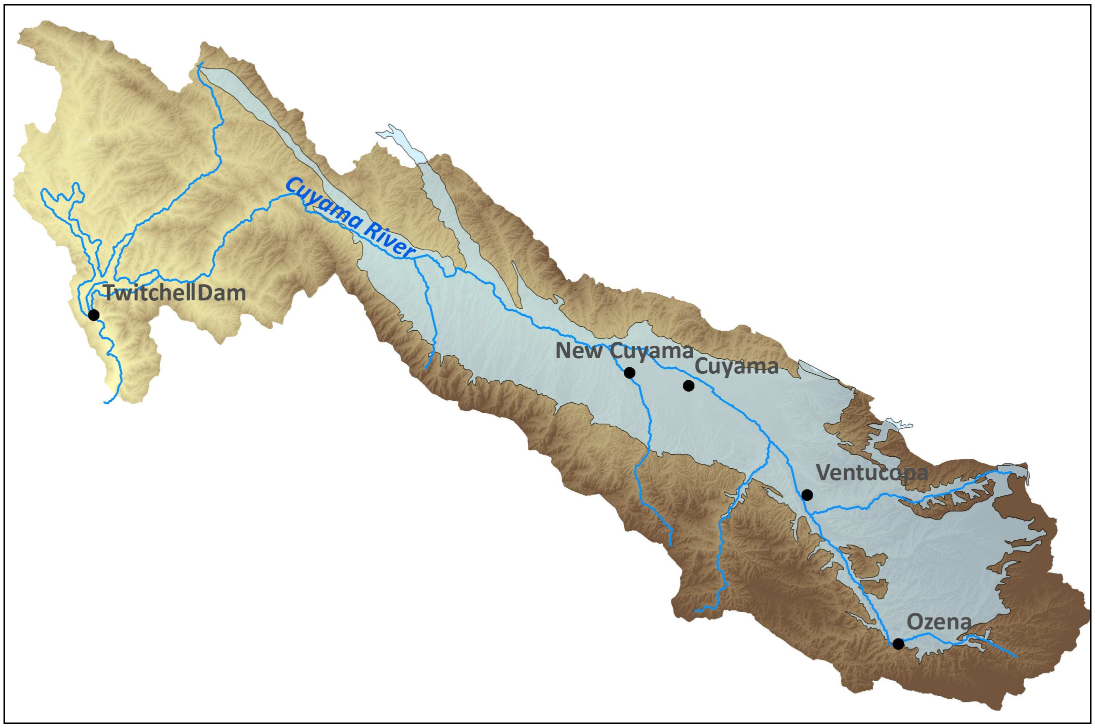


Figure 11: Location of the Cuyama Groundwater Basin (light blue) and major tributaries (dark blue)

The Cuyama Valley faces serious hydrologic impacts due to groundwater supply deficits, high evapotranspiration rates, and low annual rainfall. The USGS has been monitoring groundwater wells in the Cuyama Valley since 1938. To date, 371 groundwater wells have been monitored in the region, but the majority of these wells are no longer monitored due to well decommissioning and degeneration. Currently, seventeen wells remain actively monitored by the USGS (Figure 12, Appendix A). These monitoring sites are located in the central portion of the valley, where most agricultural pumping takes place.

Groundwater levels have declined over 300 feet over the past six decades in the southeastern section of the basin (Figure 13 & Figure 14). The variation in depth to groundwater across the agricultural zone is primarily attributed to the complexities of the sub-surface geology (described in detail in the Geology section of this report) and not due to localized differences in withdrawal. Faults near the intersection of Branch Canyon Creek and the Cuyama River create an upwelling of groundwater in a localized region (Figure 15). Natural springs were historically found in the upwelling area, but groundwater depths are no longer shallow enough to foster spring formation. Groundwater level decline near Ventucopa is less severe since the area of permeable soil deposits is smaller relative to the rest of the basin (Figure 16); therefore, groundwater recharge seems to be more significant. As a result, groundwater levels are more variable and do not experience significant trends of decline (Figure 17).

In 1980, the Cuyama groundwater basin was identified by the California Department of Water Resources as one of the eleven basins in "critical condition of overdraft," which is defined as a "continuation of present water management practices [that] would probably result in significant adverse overdraft-related environmental, social or economic impact" (California Department of Water Resources 2003b). Although the groundwater basin is experiencing serious hydrologic impacts due to unsustainable groundwater pumping practices, a groundwater management plan for the basin does not exist. Sections 10750-10756 of the California Water Code, commonly referred to as AB 3030, "provide a systematic procedure for an existing local agency to develop a groundwater management plan" (California Department of Water Resources 1999). Groundwater management may be developed by a local agency following a local vote, or mandated at the county level (California Department of Water Resources 2003b). Since the Cuyama groundwater basin lies within four counties (Kern, San Luis Obispo, Santa Barbara and Ventura) any future efforts for a county groundwater management plan will likely be difficult.

An option to limit withdrawal is for an overlying or appropriative user to bring suit to the courts causing the adjudication of the groundwater basin. This is often a lengthy process, and ends with the court setting an allowable annual withdrawal from the aquifer based on scientific evidence and appointing a "watermaster," who is an individual or agency that will set allowable withdrawal amounts per user. Only nineteen groundwater basins have been adjudicated in the state of California, and all court designated allowable withdrawals for these basins have been at more sustainable levels intended to stop or slow the further decline of the water table (California Department of Water Resources 2009).

A 1992 study prepared by Santa Barbara County contains the most current water supply and demand figures for the Cuyama groundwater basin (Baca & Ahlroth 1992). The County of Santa Barbara and the USGS are launching a study entitled *Geohydrology and Water Availability of the Cuyama Valley, California*, which is expected to be completed by the year 2012. Its main objectives are to "refine the geohydrologic framework of the Valley, quantify the hydrologic budget of the region, and develop hydrologic modeling tools to evaluate and manage the groundwater resources" (Gibbs & Hanson 2008). A more detailed description of the basin and its storage will allow for a more accurate evaluation of groundwater resources.

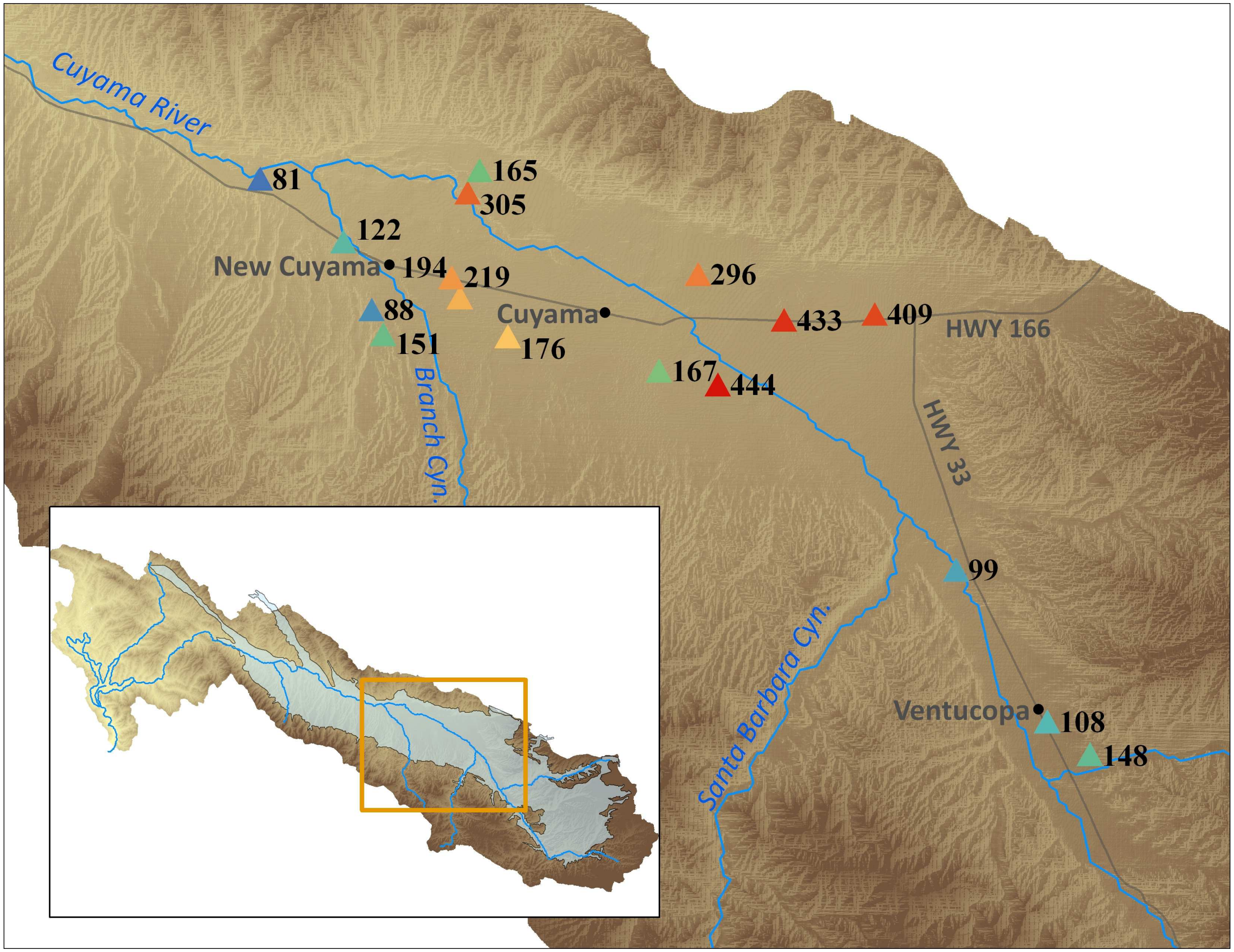


Figure 12: Depth to groundwater data in feet below land surface for the 17 active groundwater monitoring wells in the Cuyama Valley.

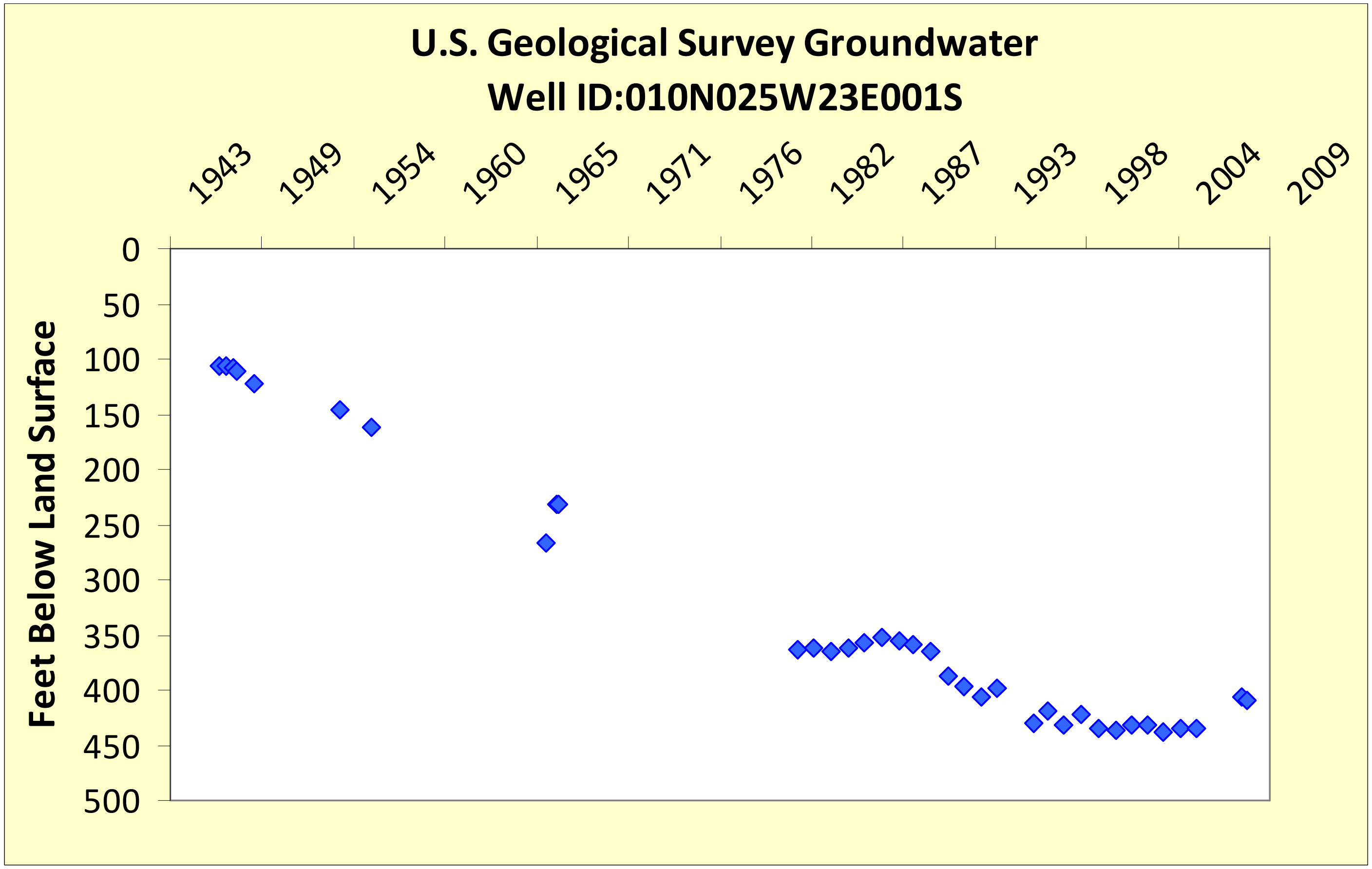


Figure 13: This well, located in the southeastern portion of the groundwater basin, has experienced a 302 ft. drop in groundwater levels over the past 60 years.

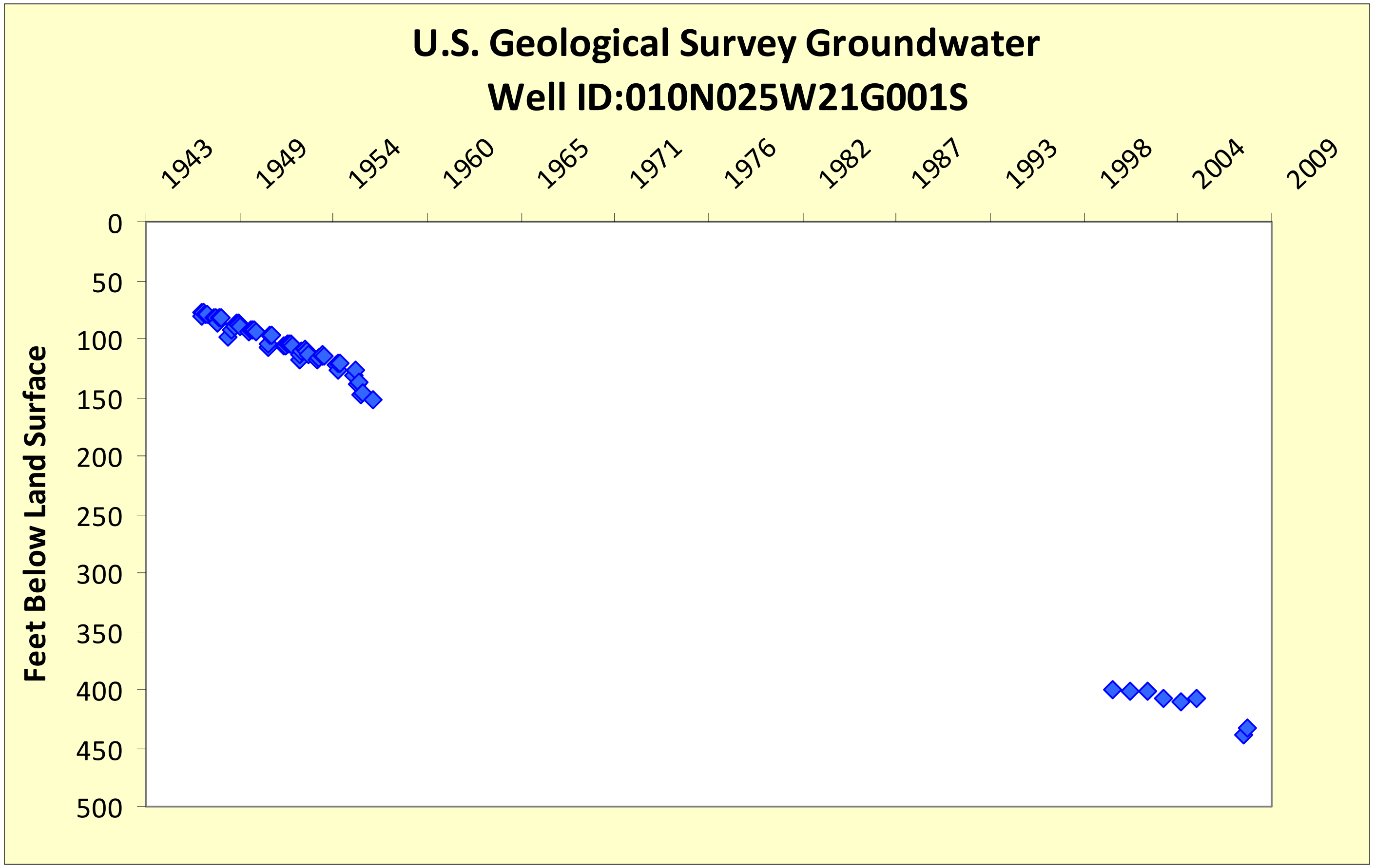


Figure 14: A drop of approximately 355 feet has occurred in this monitoring well located in the southeastern part of the basin.

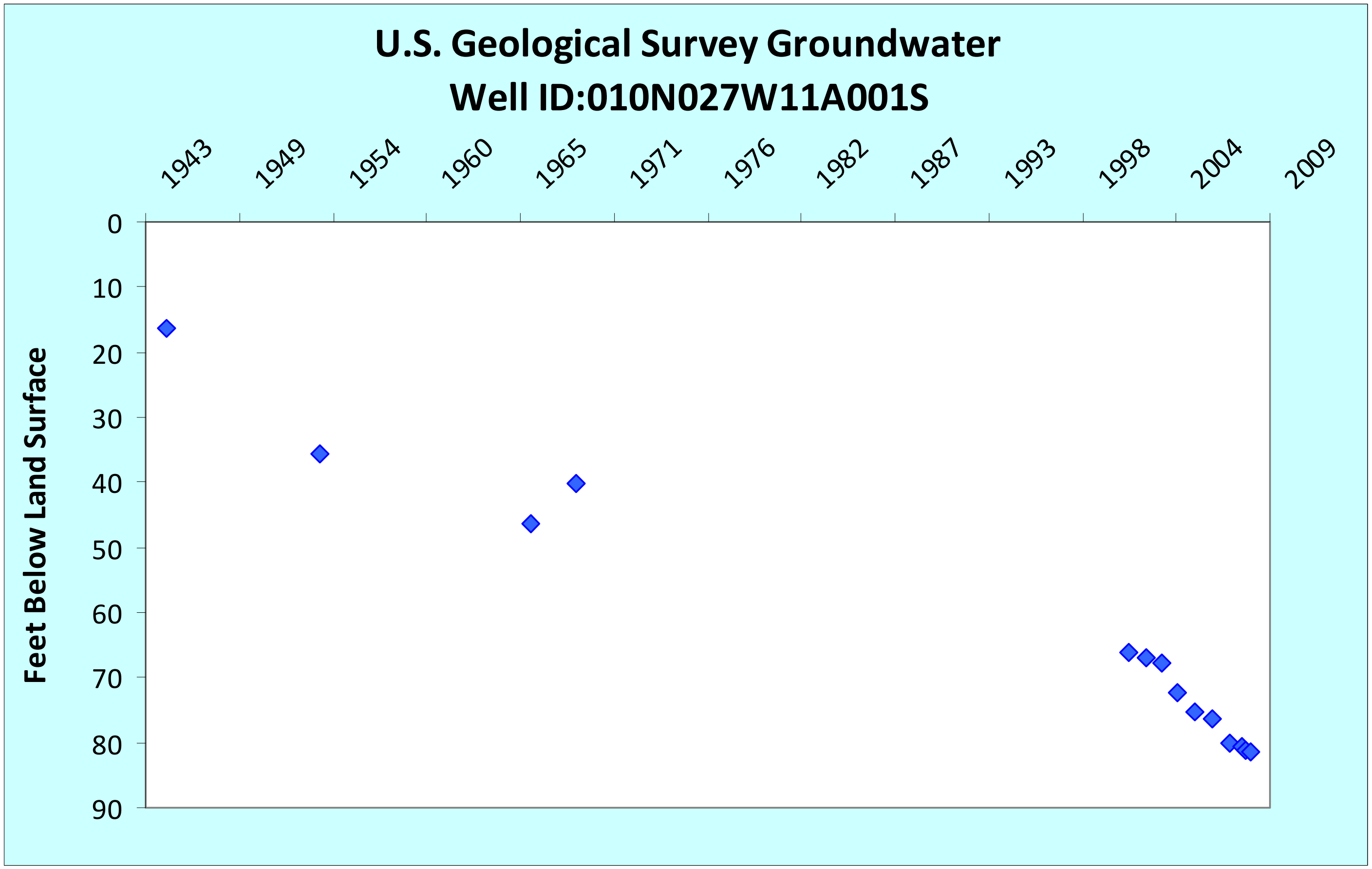


Figure 15: Groundwater level data for a well located near the intersection of Branch Canyon Creek and the Cuyama River. Groundwater level decline is not as severe as in the southeastern part of the basin.

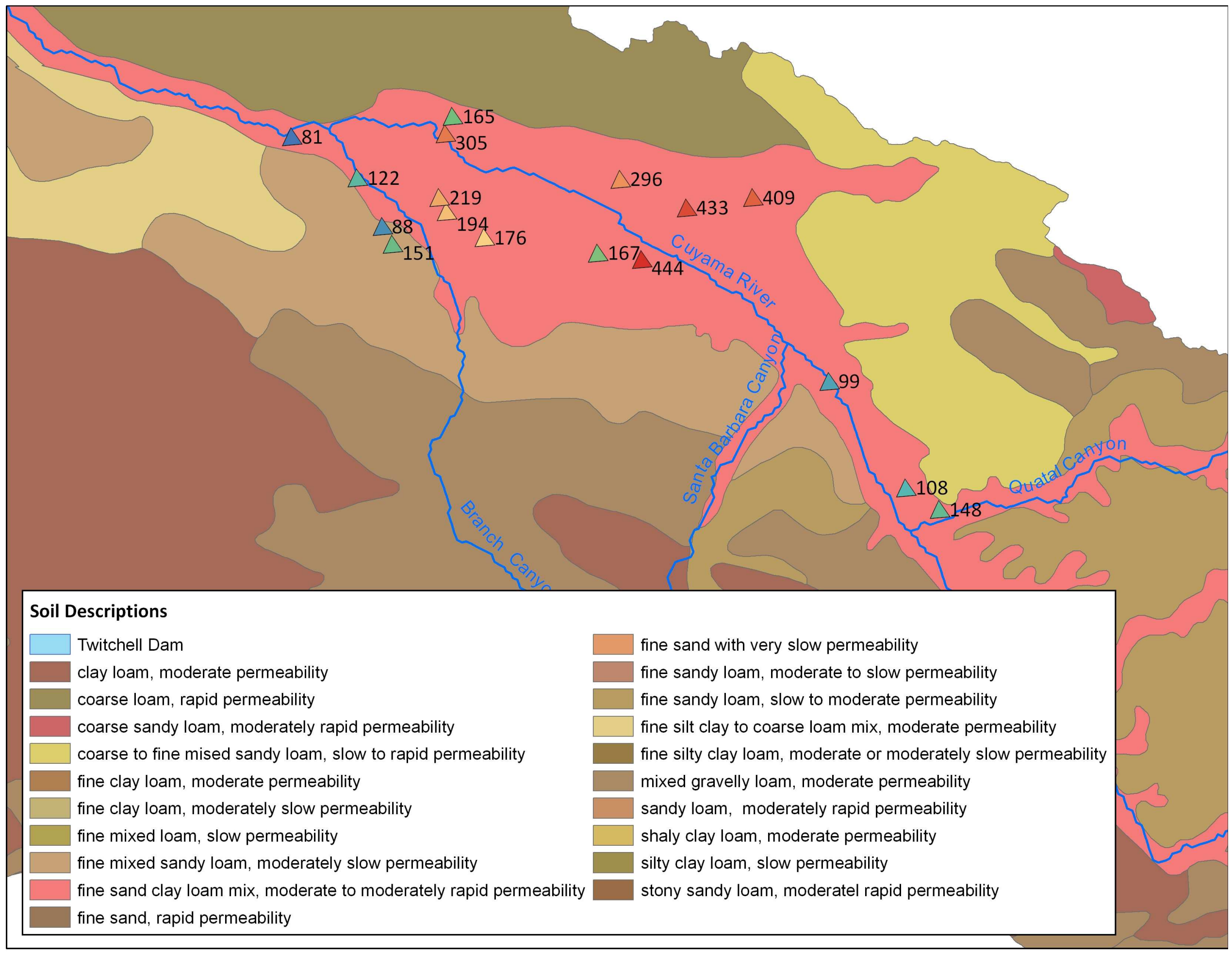


Figure 16: Depiction of the distribution of soils where the USGS groundwater monitoring wells are located. Geologic formation descriptions are available in Appendix B.

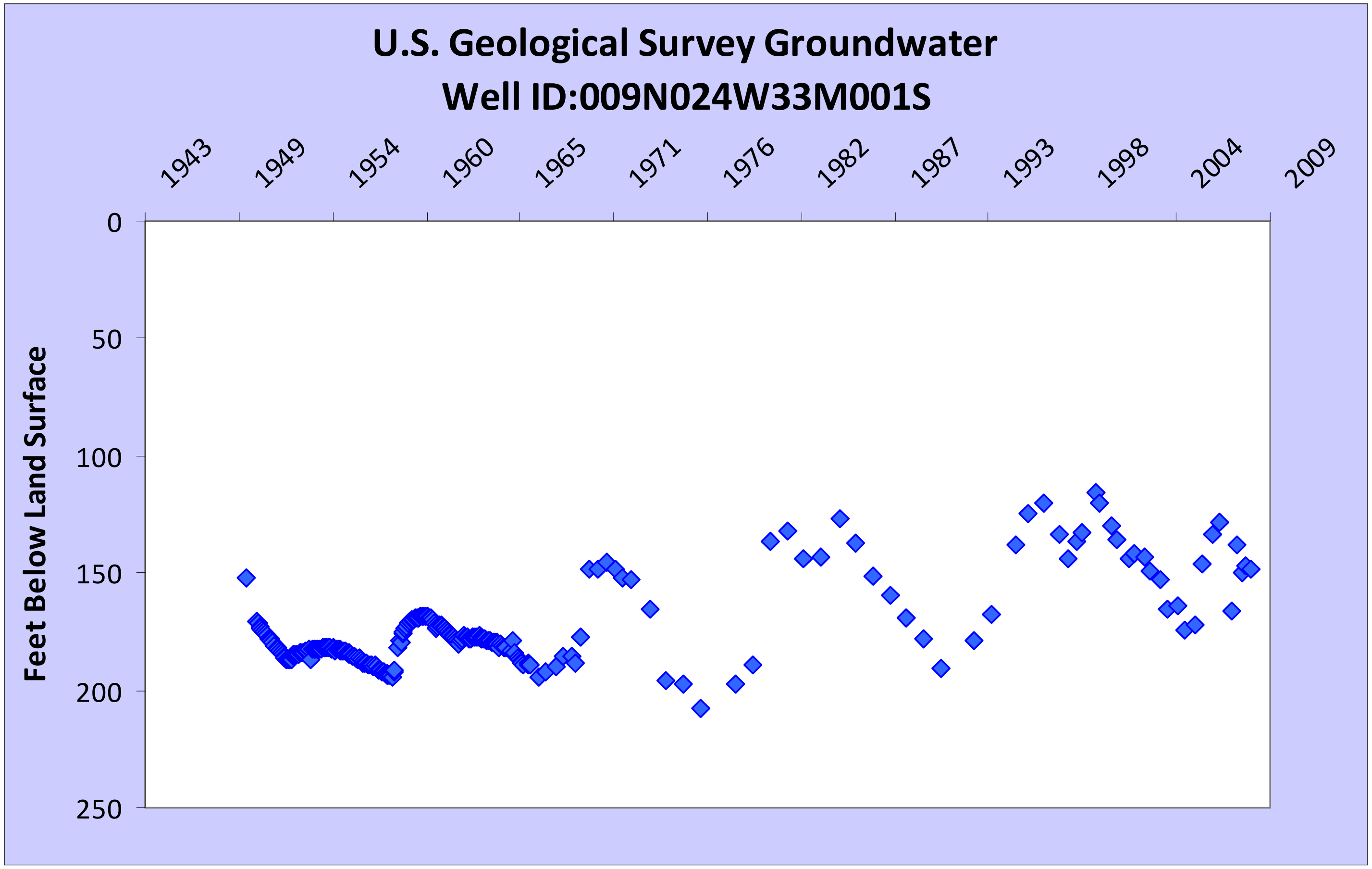


Figure 17: Data for a groundwater well near Ventucopa. This well does not experience a significant trend of decline due to groundwater recharge.

Current Groundwater Budget

There have been several attempts to develop an overall groundwater budget for the Cuyama Valley, but much of the information required to produce an accurate groundwater budget is limited and incomplete. Data from existing sources and previous estimates were compiled in attempt to produce a more accurate estimate of the current groundwater budget. Refer to Appendix A for more details on the data and calculations used to develop this groundwater budget.

The following factors were considered in the development of the groundwater budget for a typical year:

Groundwater Underflow
This is the downstream flow of groundwater. Calculating an exact value for underflow was beyond the technical scope of this project. Therefore, the most recent and thorough estimate of 500 acre-feet per year (AFY) of underflow created in a 1966 survey was utilized (Singer & Swarzenski 1970).

Baseflow
This is the amount of groundwater that seeps into a stream channel. As of 1970, there have been no observations of water table intersecting the surface (Singer & Swarzenski 1970). Therefore the baseflow for the Cuyama Valley is assumed to be zero.

Floodflow
This is the amount of stream discharge during a flood. Although a USGS stream gauging station is located near the town of New Cuyama, flow has not been monitored since 1972, rendering the calculation of a current estimate impossible. Therefore, the 9,000 AFY floodflow estimate made by Singer and Swarzenski in 1970 was used.

Vegetative Use
This is the magnitude of water loss due to evapotranspiration by native vegetation that is sustained by the groundwater aquifer. Vegetative use in Cuyama was first calculated by Upson and Worts in 1951, but the area of riparian vegetation that relies on groundwater has significantly declined; therefore an updated estimation was made. An aerial photograph from the 2005 National Agriculture Imagery Program (NAIP) was used to quantify and classify the amount of vegetation along the portion of the river where water-loving vegetation was historically found. Vegetated areas were measured and classified into three categories: swamp (tulles, cattails, and grass); dense trees, grass, and brush; and sparse grass, brush, and a few trees. Because field studies on evapotranspiration in the Cuyama Valley were not available, per-acre coefficients calibrated for the upper Salinas Valley were applied

(Upson & Worts 1951). The estimated total water consumed by current natural vegetation was calculated to be 1,440 AFY.

Net Agricultural Pumpage
This is the amount of water used for irrigation, which was determined by multiplying crop acreages with specific water requirements. We assumed pistachios, vineyards, and orchards use drip irrigation systems; therefore a return flow percentage was not applied for those crops. In some years soils are flushed out to remove salt build up but this was not taken into account in the overall groundwater budget for a given year. For the remaining crops a 30% return flow was applied, which was based on California Department of Water Resources field surveys on applied water rates and irrigation efficiency rates for agriculture in Santa Barbara County (Santa Barbara County Water Agency & Boyle Engineering Corporation 2003).

Net Municipal-Industrial Use
Municipal and industrial water use comprise a relatively small amount of water; therefore, they were calculated as a collective factor in the overall groundwater budget. The gross per capita demand for the Cuyama Valley was estimated at 215 gallons a day per person. This per capita estimate, applied to the total population in the valley (1,350), generates municipal and industrial water use. A 40% return flow (Santa Barbara County Water Agency & Boyle Engineering Corporation 2003) was then applied to obtain net water use. The net amount was rounded up to 200 AFY for the groundwater budget calculation.

Total Runoff
Precipitation runoff from the mountains sustains flow in the Cuyama River. Because reliable data on precipitation runoff within the study area is not available, a calculation made in 1970 was used. The long-term average precipitation runoff made available for groundwater recharge was estimated at 22,000 acre-feet per year (Singer & Swarzenski 1970). To account for any losses, a value of 21,000 acre-feet per year was used.

Direct recharge from precipitation on the valley floor was not taken into account in this water balance since the value is relatively small and would not have a significant impact on the overall water budget calculation.

Based on these assumptions and calculations (Appendix A), we estimate the current groundwater budget of the Cuyama Valley to be in a deficit of 30,532 acre-feet per year (Table 5). The trends of critical groundwater level decline across the valley (p. 18) seem to support such a number. This deficit exceeds the current estimated rate of recharge by almost a factor of three.

Table 5. Current Groundwater Budget for the Cuyama Valley. All values are in acre-feet/year.

Current Groundwater Budget	
Underflow	500
Baseflow	0
Floodflow	9,000
Net Agricultural Pumpage	40,392
Net Municipal-Industrial Use	200
Vegetative Use	1,440
Total Withdrawals (-)	**51,532**
Natural Runoff (+)	**21,000**
Deficit	**-30,532**

Wildlife Habitat Connectivity

Habitat connectivity provides important ecological functions relating to biodiversity, gene flow, population dynamics and species movement and dispersal (McRae et al. 2008). Given its east-west orientation, gentle topography, and position between large tracts of protected land, the Cuyama Valley seems well-suited facilitate to wildlife movement (Figure 16). Additionally, wildlife species may migrate from the coast inland along the river valley (The Nature Conservancy 2008). This habitat connectivity may prove crucial for species dispersal and adaptation to climate change. Highway 166 is the biggest impediment to species movement within the valley. Further land development and diminished water resources may degrade the existing connected habitat and threaten the viability of conservation targets. Informed foresight of potential land transformations will allow for strategic conservation efforts to mitigate threats to existing habitat connectivity.

We analyzed habitat connectivity of the Cuyama Valley for species moving north-south between the Carrizo Plain and Los Padres National Forest, as well as for species moving from coastal habitats inland east-west along the valley. Our analysis consisted of four major steps: (1) species selection, (2) development of base land use and habitat map, (3) classification of land use according to species preference, and (4) data processing using Circuitscape software.

Selection of Species for Habitat Connectivity Analysis

Nine species were considered based on their complementary habitat requirements. Species occurrence information from California Natural Diversity Database (CNDDB) and habitat use based on California Wildlife Habitat Relationships

(CWHR) database were used to narrow the list to four species representing either east-west movement along the valley in the riparian corridor (Blunt-nosed leopard lizard, Two-striped gartersnake (*Thamnophis hammondii*)) or north-south movement across the valley (San Joaquin kit fox, Pronghorn antelope (*Antilocapra americana*)).

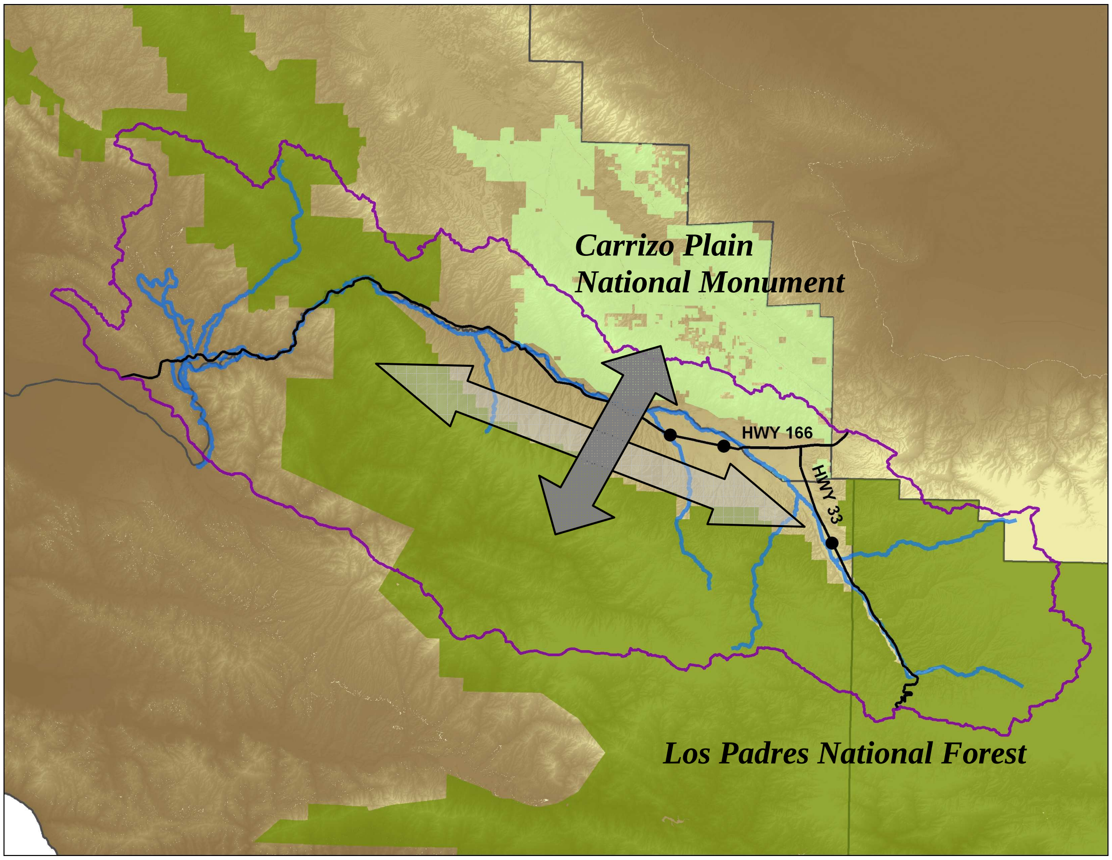


Figure 18: Illustration of potential connectivity pathways in the Cuyama Valley.

Table 6: Species considered for habitat connectivity analysis

Blunt-nosed leopard lizard	*Gambelia sila*
Two-striped gartersnake	*Thamnophis hammondii*
San Joaquin kit fox	*Vulpes macrotis mutica*
Pronghorn antelope	*Antilocapra americana*
California horned lizard	*Phrynmsoma coronatum frontale*
Giant kangaroo rat	*Dipodomys ingenus*
Nelson’s antelope squirrel	*Ammospermophilus nelsoni*
Tricolored black bird	*Agelaius tricolor*
Western spadefoot	*Spea hammondii*

Two-striped gartersnake (*Thamnophis hammondii)*

The Two-striped gartersnake is a unique species found along the California coast from the Monterey Peninsula through Baja. The species population is in decline from conversion of natural habitat, excessive livestock grazing, and flood control (NatureServe 2008). The snake requires water year-round, a sparse resource in the Cuyama Valley. It is often found in riparian vegetation such as willows, near livestock watering sites, or in rocky stream beds (NatureServe 2008). This species was chosen to model genetic connectivity east-west along the valley (Figure 17a). It is assumed the species only moves long distances in the valley during the wet winter season.

Blunt-nosed leopard lizard (*Gambelia sila*)

The Blunt-nosed leopard lizard is an endangered species that likes flat arid environments with sparse vegetation and sandy soil, allowing plenty of room to run (NatureServe 2008). They will not use lands that have been tilled for agriculture. It may take up to ten years for the lizard to re-inhabit previously tilled land. Lands surrounding agricultural areas may seem like suitable habitat, but in fact may not support populations of the leopard lizard due to pesticide spraying (NatureServe 2008). Each male can have a home range of up to 22 acres, but there may be some overlap between home ranges (NatureServe 2008). Three habitat types found in the valley are a particularly suitable for the leopard lizard including, grasslands, desert washes, and alkali flats. The species was chosen to represent east-west genetic connectivity along the valley bottom (Figure 17b).

Pronghorn antelope (*Antilocapra americana*)

Pronghorn antelope were reintroduced along with Tule elk to the Carrizo Plain National Monument (US Department of the Interior Bureau of Land Management 2007). Forbs and shrubs make up the majority of their diet with sagebrush being the most preferred shrub species. Grass is used as spring forage and may include the use of alfalfa (Hopkins 1999). Verbal accounts note that the species will travel through agricultural fields, but no literature has been found describing their use of the Cuyama Valley. Pronghorn may migrate between summer and winter ranges and move up to 90 miles between ranges (Hopkins 1999). Although this has not been documented for the population in the Carrizo Plain, the distance across our study area is only 22 miles. Given their large size, roaming grazing behavior and migrations in other areas, they were chosen to represent cross-valley movement connecting the Carrizo Plain and Los Padres National Forest (Figure 17c).

San Joaquin kit fox (*Vulpes macrotis mutica*)

The San Joaquin kit fox is a charismatic species with light rusty-brown fur and big ears. They are nocturnal animals that feed on small mammals and rodents. The fox was added to the federal endangered species list in 1967. The Cuyama Valley and Carrizo Plain represent the extreme southern end of the species range (NatureServe 2008). The fox was chosen as a generalist species for the valley as it uses many of the habitats found in the area including grasslands, pinyon-juniper shrublands, oak and pine woodlands, and desert chaparral (Figure 17d). No habitat was given a suitability rating of 100, but many habitats were assigned mid-range values (33-66). The fox uses underground dens often previously inhabited by other animals. At times they have also been observed using culverts and other large pipes as dens (NatureServe 2008).

Land Use and Habitat Mapping

Although many national and state land use/land cover maps encompass the study area, two recent products were of sufficient spatial and taxonomic detail to meet our requirements: the Landscape Fire and Resources Management Planning Tools Project (LANDFIRE, a collaboration between the USDA Forest Service and the US Department of Interior) database and the USDA Forest Service CALVEG database.

After examining both datasets in the field and in comparison to recent aerial photographs, we elected to use the LANDFIRE database. However, to achieve an acceptable level of accuracy, we combined the LANDFIRE database with other available GIS layers and layers we created based on aerial photography and field observations. Most importantly a new map of riparian habitat was created using a 2005 aerial photograph of the region to better characterize the changes in habitat observed throughout the valley. The comprehensive land use and habitat map was created by combining LANDFIRE, agriculture, industrial and residential development, roads, bridges, and the newly developed riparian layer (Table 7) (Figure 31, p. 46).

Table 7: Layers and their sources used to create the final land use map

Land Use	Source
Vegetative Communities	US Forest Service
Agriculture	Santa Barbara Agricultural Commissioner's Pesticide Use Data
Industrial and Residential	National Land Cover Dataset
Cuyama River and Riparian Area	Developed during project
Tributaries and Stream Network	National Hydrology Dataset
Roads	Bureau of Land Management
Bridges and Underpasses	CalTrans

Classification of Land Use According to Species Preference

For each of the four focal species, land use/land cover data were re-classified into a habitat suitability score by cross-walking land cover classes in LANDFIRE to wildlife habitat types used in the CWHR database and assigning suitability scores for the species. Suitability values ranged between 0 and 100, where a value of 0 means the animal will not use that habitat type and a value of 100 means the habitat has high suitability for all activities, including foraging, resting and reproduction.

Habitat Connectivity Analysis using Circuitscape Software

Circuitscape is a connectivity mapping software designed around principles of electrical circuit theory. Each fundamental component of electricity including resistance, conductance, effective resistance, effective conductance, current, and voltage are applied to landscape features as described by McRae et al. (2008). Circuit theory states that when multiple paths exist the strength of electrical current depends on the initial voltage and the arrangement of resistors. This is analogous to species movement within a landscape where animals preferentially use certain habitats and avoid others. While Circuitscape has the ability to describe a landscape in terms of genetic and physical connectivity, it also has technical limitations. Most notably, though the program is compatible with multiple computer platforms, it requires large amounts of memory to execute a relatively small number of grid cells. The study area analyzed in this project was too large at a serviceable resolution of land classification, given the constraints of computer processing power—approximately 15 million cells.

As a result, the study area was subdivided into four regions with overlapping segments that were each less than 3 million cells. Connectivity was modeled between interest points that were chosen at locations of highly suitable habitat and strategically located to model different orientations of movement. A second round of data analysis was performed to evaluate connectivity through the central region of the valley where most farming, mining and residential activities are located. A brief description of each species and the overview map for the valley are shown in the following section.

Habitat Connectivity Results

The output from Circuitscape displays species movement in terms of electrical current (Figure 19). High current (bright yellow) indicates "pinch points" where species are funneled through a narrow area. These areas could be interpreted as critical pathways. Where current is less concentrated (green to blue), many options exist for species movement. Highway 166 and 33 pose the greatest restrictions to species movement. Critical connections across the highway can be seen, most commonly indicating the location of a bridge. Additionally, oil fields contain many roads fragmenting the landscape leading to low connectivity values for all species

Despite these barriers, there is so much natural vegetation surrounding agriculture and developed lands that overall connectivity in the valley is strong. Resistance values were not obtained for the entire valley due to the segmented input maps. A more detailed discussion of resistance values for each species will be presented in the Scenario Planning section of this report.

Blunt-nosed leopard lizard and Two-striped gartersnake cannot move through agricultural or developed areas. The footprint of agriculture is most apparent in these species' maps (Figure 19a & 19b). The snake's use of the river bed to move in a linear path through agriculture is indicated by the strong yellow line in the central valley surrounded by dark blue (Figure 19a). The Pronghorn antelope map (Figure 19c) clearly shows the difference between various types of agriculture. Antelope will move through grain, alfalfa and vegetable fields, while orchards and vineyards pose more of a barrier.

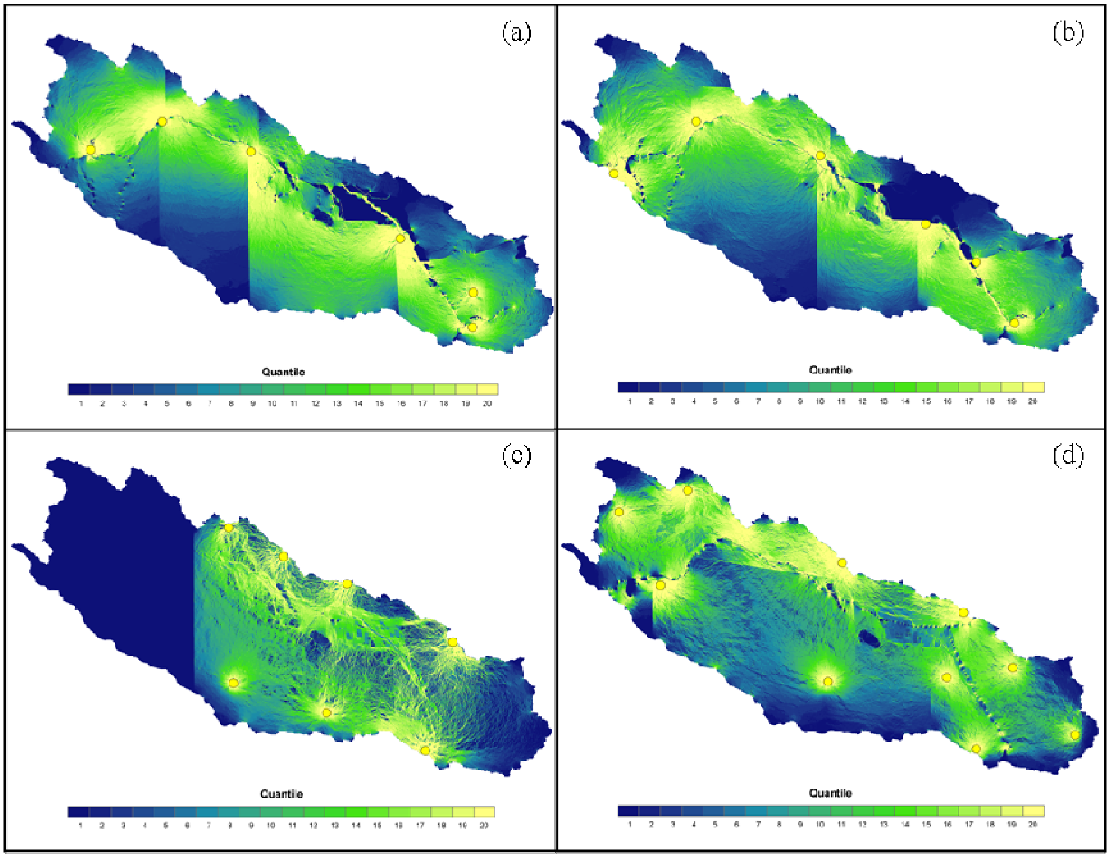


Figure 19: (a)Two-striped gartersnake east-west valley connectivity; (b) Blunt-nosed leopard lizard east-west valley connectivity; (c) Pronghorn antelope cross valley connectivity; (d) San Joaquin kit fox generalist species whole valley connectivity.

Currently 300-400 vehicles travel on the road per day (California Department of Transportation 2007). The roads are assumed to be a complete barrier for Blunt-nosed leopard lizard and Two-striped gartersnake. Neither species will cross a road of this size, regardless of traffic patterns. One the other hand, the San Joaquin kit fox and Pronghorn antelope will cross roads, but with significant risk of stress, injury, or mortality. As observed during field visits, most the bridges in the lower part of the valley are open-span bridges. These types of bridges have been proven effective for large mammals including elk and deer (Safe Passage 2007). The images below (Figure 20) highlight places important to connectivity are directly related to the bridge underpasses.

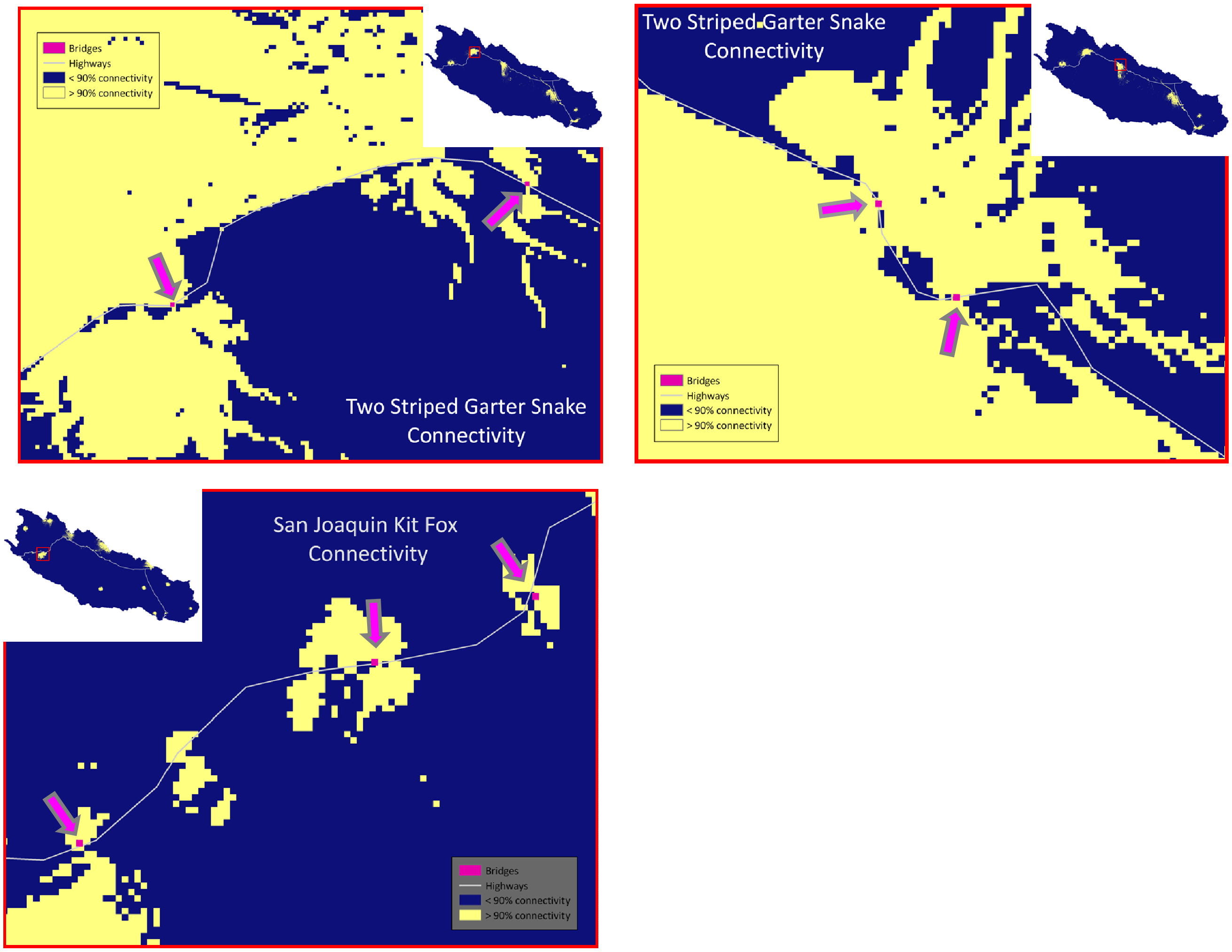


Figure 20: Locations of bridge underpasses critical for species movement. Yellow areas represent the top 10% of conductance values.

Historic Riparian Vegetation

As groundwater resources have been depleted over the years, riparian vegetation within the valley has undoubtedly changed. Gallery cottonwoods (*Populus fremontii*) may historically have been found within the river valley (Maloney 2008b). An analysis of historic aerial photographs of the river valley through time provided data as to how the decline of the water table has affected the distribution of riparian vegetation within the valley.

Four aerial photograph mosaics, from 1938, 1978, 1989, and 2005 were chosen for the historic riparian vegetation analysis. These images were geo-referenced to the 2005 NAIP aerial photograph. Each aerial image had a resolution of 1:40,000 and were obtained in color infrared when possible. The full listing of flight numbers, dates, and frames are referenced in Appendix E.

The majority of natural vegetation within the valley subsists on natural precipitation. However, according to published literature from 1951, approximately 2,100 acres along the Cuyama River historically contained vegetation that relied on groundwater (Upson & Worts 1951). This vegetation reportedly extended downstream to Bee Rock Canyon, where highway 166 crosses the Cuyama River (Figure 21). Specifically, 1,650 acres were identified as tulles, cattails, and grass; 150 acres were categorized as dense trees, grass, and brush; and the remaining 300 acres were identified as sparse grass, brush, and trees (Upson & Worts 1951).

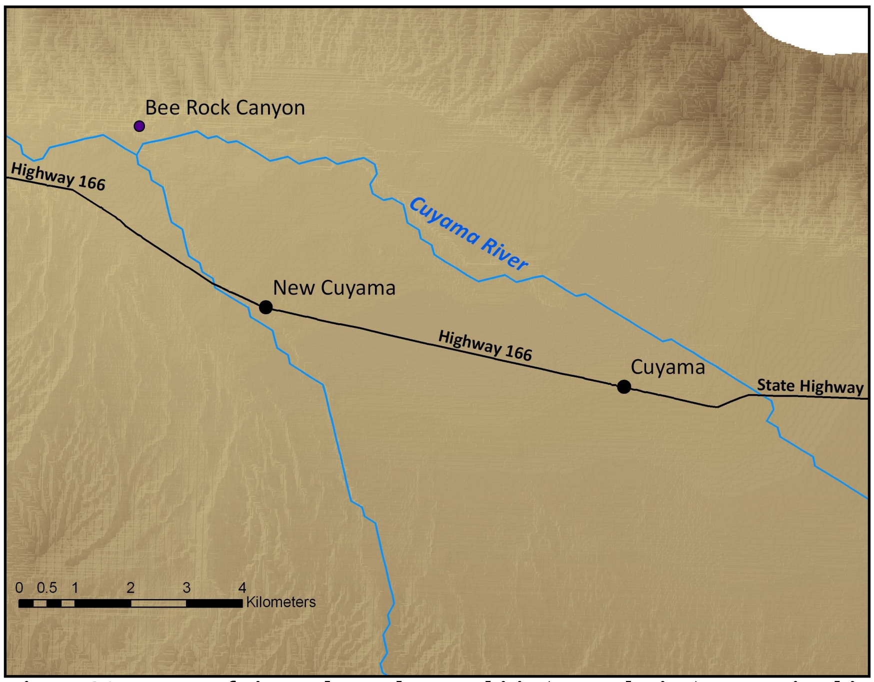


Figure 21: Extent of river where phreatophitic (water-loving) vegetation historically occurred.

Qualitative Analysis

Visual inspection of historical aerial photographs revealed a significant loss of riparian vegetation concurrent with the expansion of intensive agriculture (Figure 22). The 1938 photograph depicts a region along the Cuyama River channel that contained identifiable riparian vegetation. In the photograph, riparian vegetation appears as a dark, mottled texture surrounding the river channel that is distinct from the lighter and comparatively smoother grassy uplands. In the 1978 photograph, patches of dark vegetation remain, but are conspicuously absent in subsequent years. As the agriculture intensified and encroached upon the river channel, much of the visible, woody riparian vegetation historically present along the Cuyama River was lost.

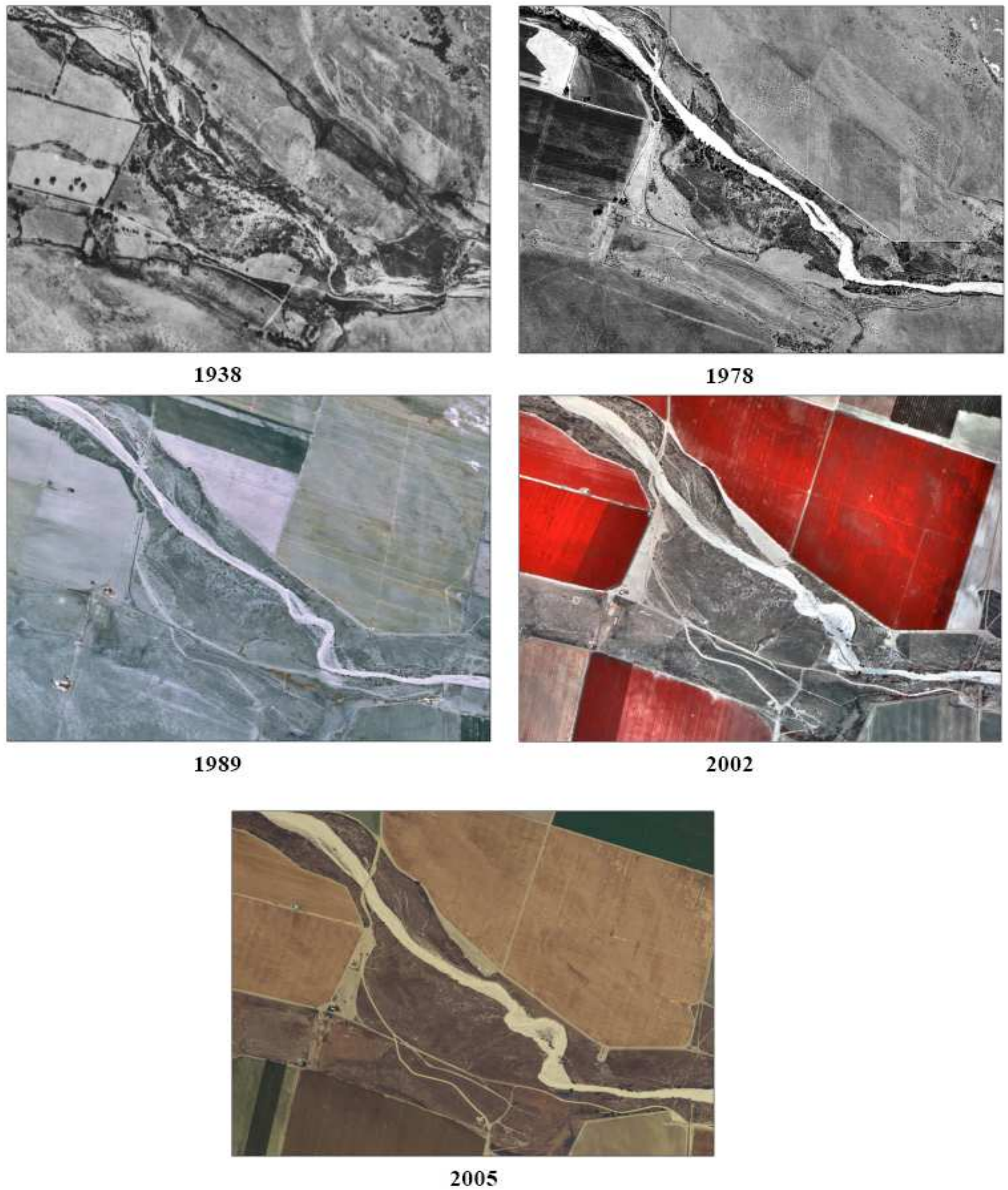


Figure 22: Illustration of the qualitative comparison of the riparian vegetation.

Quantitative Analysis

To quantify changes to the riparian zone over time, eighteen transects perpendicular to the river were established at approximately 1 mile (1.6 km) intervals along the river in 1938, 1978, 1989 and 2005 aerial images. Analysis of the river spans 27.5 km, and was centered in the portion of the valley currently utilized for intensive agriculture (Figure 23, Table 8). Channel and woody vegetation in the active riparian area were measured across each transect using the measure tool in ArcGIS 9.3. For this analysis, areas dominated by trees or shrubs were classified as woody vegetation. Bare or sparsely vegetated areas were classified as active channel. In areas where the channel was braided, segments in each class were summed.

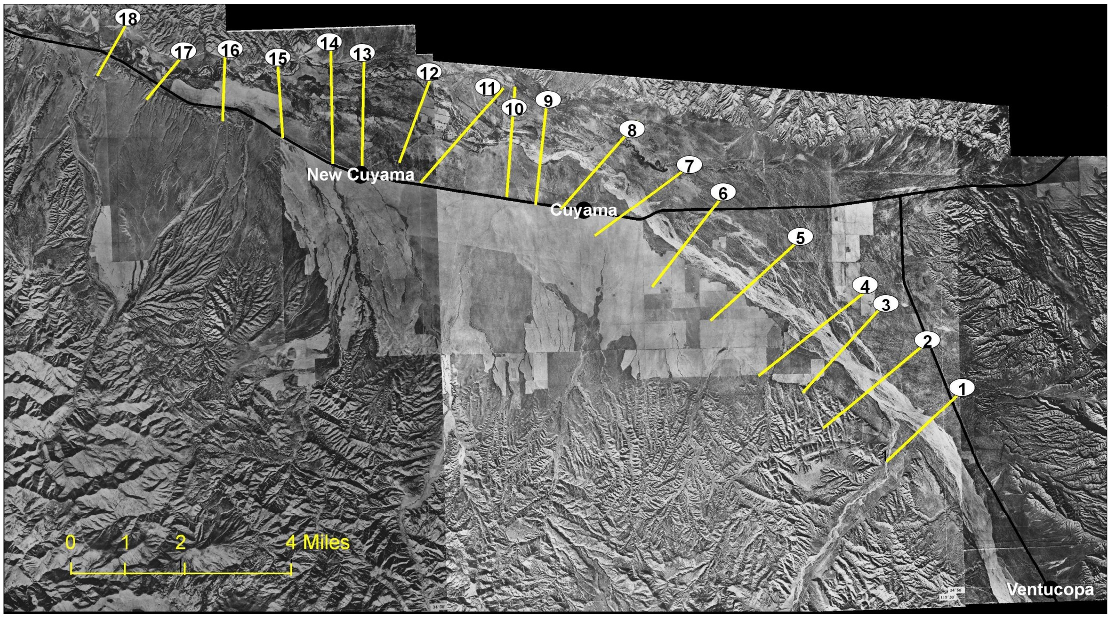


Figure 23: Placement of transects in 1938 aerial image for riparian analysis.

Table 8: Transect distance for riparian analysis.

Transect	Distance (km)	Transect	Distance (km)
1	0	10	15.1
2	1.83	11	16.4
3	3.27	12	18.0
4	4.20	13	19.9
5	6.61	14	20.9
6	8.95	15	22.4
7	10.6	16	24.1
8	12.3	17	25.7
9	14.1	18	27.5

Total riparian width (width of the river channel plus woody vegetation) tends to diminish downstream, and it is clear that the largest portion of riparian area was lost in transects 3 through 6 after 1938 (Figure 24). These transects are located in the portion of the valley that has experienced the greatest decline in the groundwater table. Changes in woody vegetation and channel area are far less dramatic in the other transects, as well as between 1978 and 2005.

Total woody vegetated area has decreased 42% from 1938 to 2005. In nine of the eighteen transects the maximum amount of woody vegetation was seen in 1938.

However, 1938 also contained the minimum amount of woody vegetation in four transects (Figure 25). On average, woody riparian vegetation has not changed significantly between years (1938, 48%; 1978, 49%; 1989, 48%; 2005, 35%). These results indicate that changes in the riparian vegetation declined in proportion to changes in the river channel width.

The overall results from this analysis suggest that the observed narrowing of the river channel and proportional loss of riparian vegetation can be attributed to the combined effect of groundwater extraction and land conversion to agriculture.

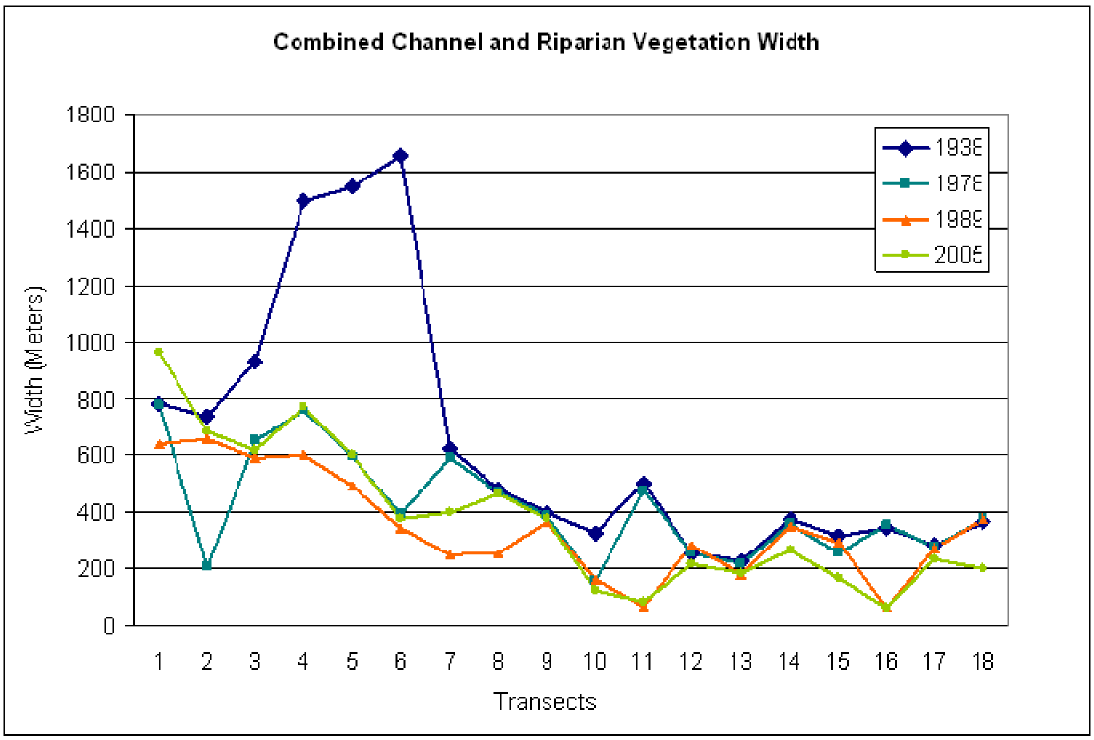


Figure 24: Combined channel and woody vegetation width through time.

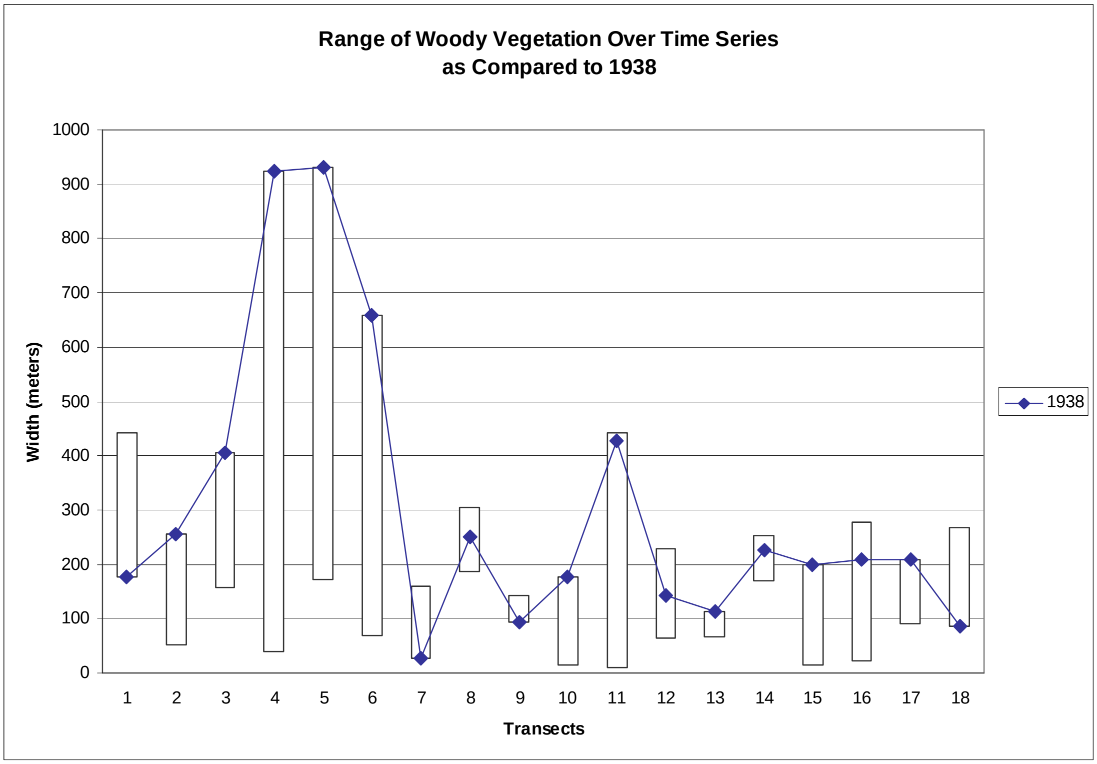


Figure 25: Range of woody vegetation over time series as compared to 1938.

SCENARIO PLANNING

To evaluate potential threats to sensitive communities, habitat connectivity, and groundwater in the Cuyama Valley four scenarios were developed to illustrate possible changes to the region that may occur by the year 2050. The scenarios are entitled: Ghost Town, Wine Country, Satellite City, and Nature Preserve. These scenarios are designed to compare possible trends in the economic development of the region, along with shifts in patterns of residential development, demographics, land use, and water availability. Scenarios were designed to represent end points of thematic change to the region to evaluate the full range of possible impacts to conservation interests. The following three point diagrams (Figure 26) illustrate the fundamental differences of each scenario along three axes of comparison, extent of agriculture, magnitude of human development, and level of dedicated conservation activity. Charts that accompany each scenario description (Figures 27 – 30) indicate the anticipated outcomes of that scenario relative to current conditions. The indicated change is qualitative and the size of the arrow conveys differing magnitudes of change where appropriate. Horizontal arrows represent little change from current conditions.

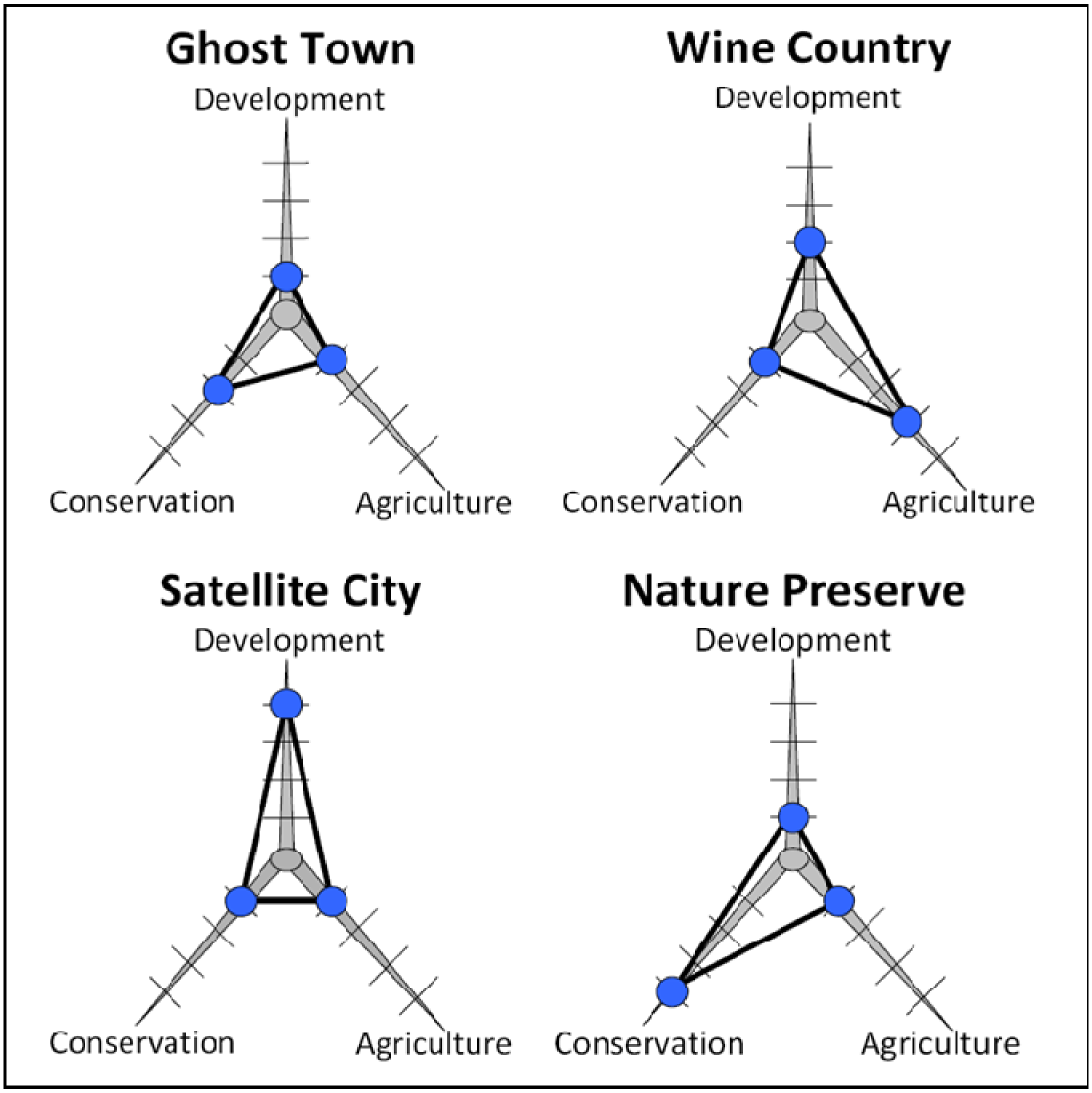


Figure 26: Illustration of basic scenario components.

Ghost Town

Description: The Cuyama Valley groundwater basin is depleted to the point where irrigated agriculture is no longer viable. Land previously used for agriculture either reverts to natural vegetation, or is utilized for livestock grazing. With no replacement industries, population in the valley decreases drastically, and the towns of Cuyama and New Cuyama are effectively deserted.

Key Drivers: Groundwater Depletion, Low Regional Economics, Zero Rreplacement Industry

Will Not Happen Without: Continued Groundwater Depletion

Ghost Town			
Elements	**Change**	**Elements**	**Change**
Houses, Businesses and Infrastructure	↓	Agriculture	↓
Year-round Residents	↓	Renewable Energy	↑
Daily Traffic	↓	Total Water Use	↓
Recreational Use of Public Lands	→	Species Connectivity	↑
Gravel Mining	↓	Oil Development	↓

Figure 27: Anticipated results of the Ghost Town scenario.

Ghost Town Methodology

In this scenario, areas designated as agricultural lands in the land cover map were changed to grasslands or scrubland. Existing urban areas and roads were preserved in the land cover map to represent the remaining infrastructure. In the water balance calculation for this scenario, net human use of water was reduced to zero since there are no agricultural, domestic, or industrial activities taking place. All other factors in the water budget were assumed to remain unchanged from current conditions. It was also assumed that the amount of natural vegetation relying on groundwater decreased to a little over half of the current value.

Wine Country

Description: The region becomes a hot spot for getaway weekend vacationers and is developed in a style epitomized by central coast winery towns such as Santa Ynez and Carmel Valley. The towns of Cuyama and New Cuyama remain small with few year-round residents, but with increased retail and hospitality infrastructure. The economy is dominated by service-oriented business providing boutique lodging, fine dining, and local viticulture. Most large-scale row crop agriculture is converted to vineyard or fruit and nut orchards. In the upper valley near Ventucopa, ranchette style housing is introduced at the current allowable rate set in the zoning ordinance. The majority of the land that has not been converted to viticulture, orchard, or ranchette development is retained for ranching. Groundwater remains the only source of water in the valley.

Key Drivers: Transition to High Value Crops, High Regional Economics, Emergent Tourism Appeal

Will Not Happen Without: Coordinated Private Investment

Wine Country			
Elements	**Change**	**Elements**	**Change**
Houses, Businesses and Infrastructure	↑	Row Crop Agriculture	↓
Year-round Residents	↑	Vineyards	↑
Daily Traffic	↑	Orchards	↑
Weekend Traffic	↑	Total Crop Acreage	↓
Recreational Use of Public Lands	↑	Total Water Use	↓
Gravel Mining	↓	Species Connectivity	↑
Oil Development	↓		

Figure 28: Anticipated results of the Wine Country scenario.

Wine Country Methodology

Development in the Wine Country scenario was constrained to the maximum number of twenty-acre wineries that a perennial yield of 8,000 AFY would allow. Perennial yield is defined as the "amount of usable water from a groundwater aquifer that can be economically withdrawn and consumed each year for an indefinite period of time" (State of Nevada Department of Conservation and Natural Resources Division of Water Resources 2009). This amount of water cannot exceed natural groundwater recharge. Because groundwater recharge estimates are so variable, a conservative perennial yield of 8,000 AFY reported in a 1992 study was used to calculate total sustainable population (County of Santa Barbara Water Resources 1992)

In the water balance calculation for this scenario, the only two factors that were adjusted were water use from the municipal and industrial (M&I) sector and from agriculture. A Santa Barbara County groundwater EIR report produced in 2006 provided figures for the anticipated yearly water consumption associated with wine production, estate landscaping, employee use employment, and visitor use. On average, a twenty-acre winery with a tasting room will use 18.59 AFY of water (County of Santa Barbara County Executive Office 2006). This figure of 18.59 AFY was used as the M&I water demand for this scenario. Additionally, vineyard cultivation in the Cuyama region with a drip irrigation system requires an average of 2.8 feet of water per acre each year (San Luis Obispo County Water Resources 1998). Thus, the annual irrigation requirement of a twenty-acre vineyard is roughly 56 AFY. Adding the water requirements of wine production and tourism, the average twenty-acre vineyard demands roughly 75 AFY. A baseline perennial yield of 8,000 acre-feet allows for the development of roughly 105 twenty-acre vineyards or 2,100 acres devoted to viticulture (Appendix A). An agricultural return flow of 0 % was assumed in this scenario since orchards and vineyards use drip-irrigation systems.

Although this scenario assumes wineries are the preferred course of development, fruit or nut orchards may be substituted with comparable water demand schedules. Diffuse residential development and the conversion of row crop agriculture to vineyards were incorporated into the scenario land use map used for the habitat connectivity analysis.

Satellite City

Description: Regional economic expansion has created demand for housing and development for the areas surrounding Santa Maria. This demand spurs the growth of Cuyama and New Cuyama and the cities merge to become a new population center. Groundwater resources are entirely diverted from agriculture to support urban development. The resulting city will be of similar size to present day Santa Maria, approximately 48,000 people. Private lands outside the city limits are used for ranching, as well as solar and wind renewable energy production. City residents are employed throughout the region and primarily commute to Santa Maria, Ojai, Santa Barbara and Bakersfield.

Key Drivers: Expansion in Regional Residential Demand, High Regional Economics

Will Not Happen Without: Major Regional Growth

Satellite City			
Elements	**Change**	**Elements**	**Change**
Houses, Businesses and Infrastructure	↑	Oil Development	↑
Year-round Residents	↑	Agriculture	↓
Daily Traffic	↑	Renewable Energy	↑
Recreational Use of Public Lands	↑	Total Water Use	→
Gravel Mining	↑	Species Connectivity	↑

Figure 29: Anticipated results of the Satellite City scenario.

Satellite City Methodology

The total sustainable population for the Cuyama Valley was determined by dividing the perennial yield (8,000 AFY) of the underlying aquifer by the average consumption of water for the region (Appendix A). This population increase was modeled on the landscape for the purposes of habitat connectivity analysis. An average density of 4,100 people per square mile was determined from population and city size data for the nearby cities of Santa Barbara, Santa Maria, Camarillo and Lompoc (IDcide 2009), dictating an urban area of approximately 12 square miles. Urbanized area was added to the land cover map for this scenario around the existing towns of Cuyama and New Cuyama. Land previously used for agriculture, orchards and vineyards was converted to grassland and scrubland.

Because build-out was limited by the perennial yield of the groundwater basin, specific water use requirements for the Satellite City Scenario were not calculated. To obtain net water use for this sector for the water balance calculation, a 40% municipal and industrial return flow was taken into consideration and a final net-value of 4,800 AFY was used. This 40% return flow was based on the 2003 Santa Barbara County Water Supply and Demand Update (Santa Barbara County Water Agency & Boyle Engineering Corporation 2003).

Nature Preserve

Description: The Cuyama Valley becomes a conservation area linking the Carrizo Plain National Monument and Los Padres National Forest. Large parcels of land are acquired by conservation entities or managed with the aim of maximizing the conservation potential of the area. The groundwater basin is adjudicated, which drastically limits the amount of water available for agricultural activities. Ranching continues but grazing is managed to improve the grasslands ecosystem. Conservation easements limiting development are placed on most properties in the valley. Invasive species such as Tamarisk (*Tamarix spp.)* are controlled. Regional and national organizations actively work to restore lands previously used for agriculture to natural scrub and grasslands.

Key Drivers: Active Conservation, Low Regional Economics

Will Not Happen Without: Coordinated Investment in Conservation

Nature Preserve			
Elements	**Change**	**Elements**	**Change**
Houses, Businesses and Infrastructure	↓	Oil Development	↓
Year-round Residents	↓	Agriculture	↓
Daily Traffic	↓	Ranching	↓
Recreational Use of Public Lands	↑	Total Water Use	↓
Gravel Mining	↓	Species Connectivity	↑

Figure 30: Anticipated results of the Nature Preserve scenario.

Nature Preserve Methodology

The natural state of the valley was modeled by converting all urban and agricultural areas to grasslands and scrublands. Roads within urbanized areas were removed. However, roads outside urbanized areas were preserved. As in the Ghost Town scenario, net human use of water was reduced to zero because of the lack of human activities in the valley (Appendix A). A modest 10% increase in vegetation acreage was assumed due to active restoration efforts in the riparian zone. The remaining elements of the water balance were assumed to remain unchanged from current conditions.

Scenario Impacts on the Groundwater Budget

The current groundwater budget was adjusted to reflect changes in water use for each scenario (Table 9). It is important to reiterate that all of the scenarios were designed around sustainable use of groundwater and that no new water supplies are brought to the region to support new development. In addition it was assumed that climate change does not heavily impact the region by 2050.

In all scenarios, the groundwater budget is no longer in a state of deficit. For example, there is now a small surplus in the Wine Country scenario even though agriculture is still expected to be the dominant user. There is a relatively large surplus in the Satellite City scenario, which can be attributed to the 40% urban return flow assumed for this scenario. Both the Ghost Town and Nature Preserve scenarios experience significant surplus conditions due to the lack of groundwater extraction for human use. Although the groundwater basin demonstrates surplus conditions in all scenarios, it would take an appreciable amount of time to recharge the basin to pre-agricultural conditions.

Table 9: Water Balance Calculations for Current Conditions and the Four Different Potential Future Scenarios in the Cuyama Valley. Note: All values are in acre-feet per year.

	Current Conditions	**Ghost Town**	**Wine Country**	**Satellite City**	**Nature Preserve**
Underflow from Study Area (AF/Y)	500	500	500	500	500
Baseflow (AF/Y)	0	0	0	0	0
Floodflow (AF/Y)	9,000	9,000	9,000	9,000	9,000
Natural Runoff (AF/Y)	21,000	21,000	21,000	21,000	21,000
Net Agricultural Use (AF/Y)	40,392	0	7,326	0	0
Net Municipal-Industrial Use (AF/Y)	200	0	2,192	4,800	0
Natural Vegetative Use (AF/Y)	1,440	840	1,440	1,440	2,148
Total Withdrawals (AF/Y)	51,532	10,340	20,458	15,740	11,648
Deficit/Surplus (AF/Y)	**-30,532**	**10,660**	**542**	**5,260**	**9,352**

Scenario Impacts on Habitat Connectivity

Land use maps were modified to reflect land use changes in each scenario. A new Circuitscape analysis was run, focusing on the portion of the valley where the most significant land use changes are expected to occur (Figure 31).

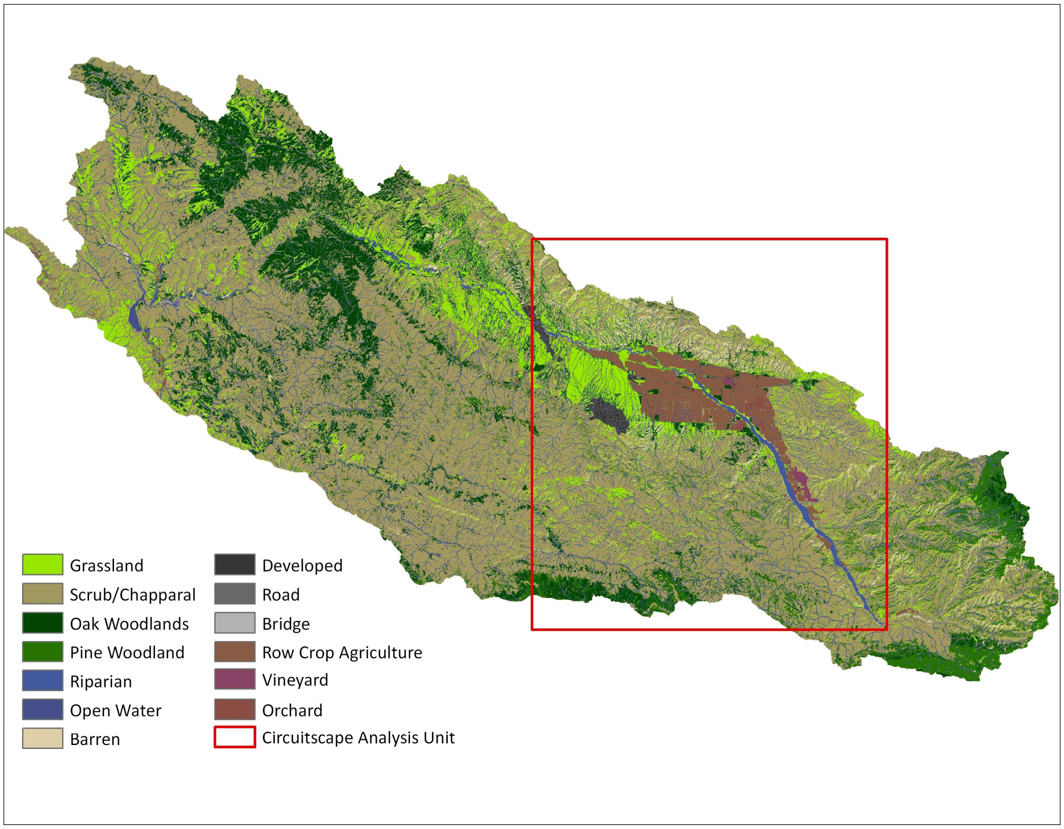


Figure 31: The portion of the valley analyzed for scenario connectivity.

On average, current conditions have the greatest degree of species resistance (i.e. lowest connectivity) to movement (Figure 32). The average resistance under current conditions for Blunt-nosed leopard lizard is twice that of San Joaquin kit fox or Pronghorn antelope. McRae and Beier (2007) have shown that resistance values generated from Circuitscape are a better indication of genetic variability between species populations than other models such as least-cost path. Without specific populations for the species studied it is unclear whether the numbers accurately correspond to genetic differences in the Cuyama Valley. Even though the Blunt-nosed leopard lizard average resistance distance is twice that of other species, the maximum pairwise value is still less than 0.09. Our results show very low resistance to species movement and thus connectivity is relatively high throughout the valley under current conditions as well as under a range of plausible scenarios.

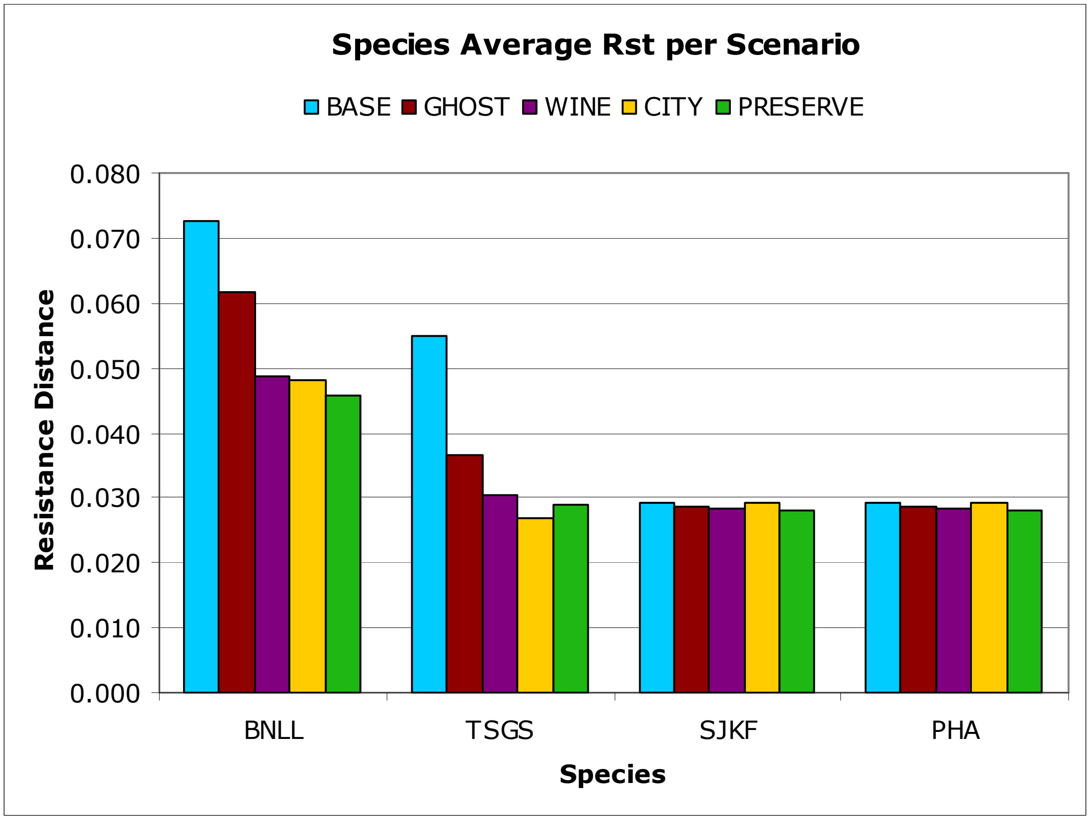


Figure 32: Average resistance for each species and each scenario. Abbreviations are as follows: BNLL, Blunt-nosed leopard lizard; TSGS, Two-striped gartersnake; SJKF, San Joaquin kit fox; PHA, Pronghorn antelope.

More in-depth examination of the pairwise resistance values shows other interesting trends (Figure 33, p. 50). The Satellite City scenario has the lowest resistance values between all points for the Two-striped gartersnake. It also has the lowest resistance values between some interest points for the other species but not all. This is an unusual result, as it is hard to imagine a city with the associated traffic being less impactful to species movement than current conditions. This result is partially attributed to the way roads were modeled.

Blunt-nosed leopard lizard and Two-striped gartersnake will not cross the road under current conditions, so roads were given a suitability value of 0. Roads for the other species were assigned suitability values less than 15 for current conditions. This value was reduced in the Satellite City scenario, but results indicate that the difference in suitability was not large enough to significantly alter average resistance values. Secondly, the extent of the Satellite City is smaller than current agriculture due to the assumption that development is constrained by sustainable water use. The smaller footprint contributed to lower resistance values seen in the output from Circuitscape.

Additionally, it is interesting to note that the Wine Country scenario and the Satellite City scenario have almost the same values for the Blunt-nosed leopard lizard, but different values for the Two-striped gartersnake. The footprint of the Satellite City is focused around the current towns of Cuyama and New Cuyama, whereas the vineyard expansion modeled in the Wine Country scenario is focused around Ventucopa. Since both residential development and agriculture significantly impact the snake's movement, we interpret the higher values of resistance in the Wine Country scenario as an indication that the habitat in the upper watershed, near Ventucopa, is more important for the snake than the lizard.

Graphs showing additional subtleties can be found in Appendix B. Regardless of subtle differences between species and scenarios, connectivity is relatively high in the valley for all species under current condition and plausible scenarios.

CONCLUSIONS

Results from our analysis allow us to form several general statements regarding the current status of conservation interests in the valley as well as the likely impacts of future development scenarios.

- **Loss of historically present riparian habitat has occurred**

Analysis of historic aerial photographs indicates there has been an appreciable loss of riparian habitat historically present in the valley due to the encroachment of agriculture and the decline of the groundwater table. Measurement of eighteen transects through time along the Cuyama River showed a decline in riparian vegetation, river channel width, and channel complexity since the first available aerial photograph of the region in 1938. Due to the depletion of groundwater resources and expansion of agriculture into the riparian zone, it is unlikely that riparian vegetation will return without active restoration.

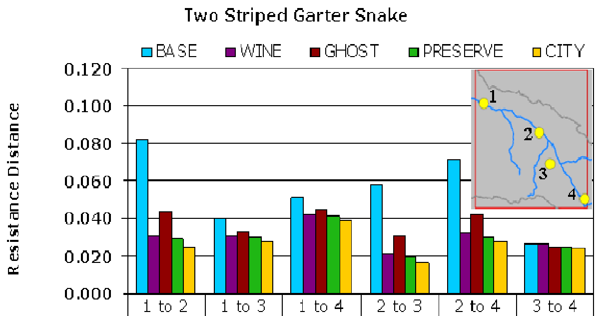
- **The groundwater basin has been critically impacted but development with sustainable use of groundwater is possible**

Our results indicate that the current groundwater demand exceeds the natural rate of recharge by a factor of three. If this rate of groundwater withdrawal continues, we estimate that the total available storage will deplete in approximately 50 years. Exhaustion of groundwater would severely limit economic opportunities in the valley, most likely resulting in a future for the region that closely resembles the Ghost Town scenario. However, results from the Wine Country and Satellite City scenarios illustrate that major shifts in agriculture and residential development are possible with groundwater extraction equal to the rate of natural recharge. For example, water use equal to natural recharge could support an urban population of 48,000 or a conversion to over 2,000 acres of high value agriculture such as orchards and vineyards. To preserve the economic and ecological viability of the valley, future land use should be tied to sustainable groundwater use.

- **Habitat connectivity is not substantially impacted by current land use and is improved through every modeled scenario**

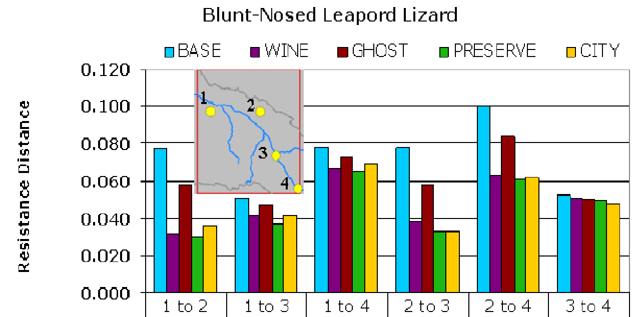
Our analysis of the habitat connectivity for the four species revealed that species movement and genetic connectivity are not significantly impaired by current land use practices in the valley. Our results also indicate that connectivity improves over current conditions in every modeled scenario, though the improvements are marginal given the strong current connectivity in the valley.

The only appreciable barriers to species movement evident in each scenario are Highways 166 and 33. Although the current distribution of bridge underpasses appears to provide connectivity across the roadways, species movement across highways through underpasses is uncertain. Additionally, because roads and underpasses significantly influence connectivity, highway expansion or reconfiguration may affect connectivity in the study area. Research on impacts to species from these highways and an analysis of the options that best fit the Cuyama Valley would help ensure habitat connectivity remains strong.



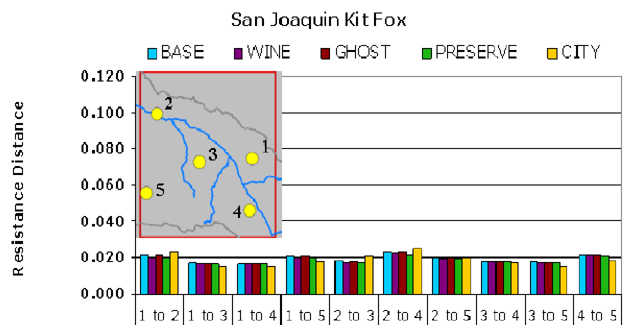
	1 to 2	1 to 3	1 to 4	2 to 3	2 to 4	3 to 4
BASE	0.082	0.040	0.051	0.058	0.072	0.026
WINE	0.031	0.031	0.042	0.021	0.032	0.026
GHOST	0.044	0.033	0.045	0.031	0.042	0.025
PRESERVE	0.029	0.030	0.041	0.019	0.030	0.025
CITY	0.025	0.028	0.039	0.016	0.028	0.024

Pairwise Interst Points



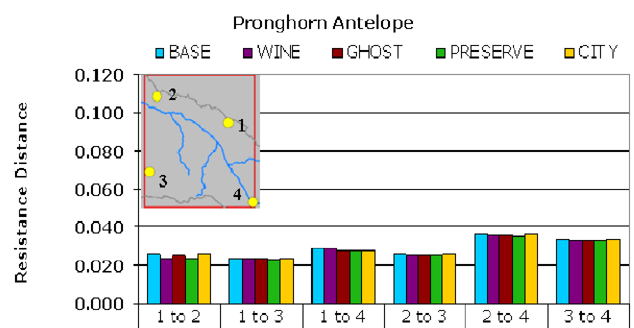
	1 to 2	1 to 3	1 to 4	2 to 3	2 to 4	3 to 4
BASE	0.077	0.051	0.078	0.078	0.100	0.052
WINE	0.032	0.041	0.067	0.038	0.063	0.051
GHOST	0.058	0.047	0.073	0.058	0.084	0.050
PRESERVE	0.030	0.037	0.065	0.033	0.061	0.049
CITY	0.036	0.041	0.069	0.033	0.062	0.048

Pairwise Interest Points



	1 to 2	1 to 3	1 to 4	1 to 5	2 to 3	2 to 4	2 to 5	3 to 4	3 to 5	4 to 5
BASE	0.022	0.017	0.016	0.021	0.018	0.023	0.020	0.018	0.017	0.022
WINE	0.020	0.016	0.016	0.020	0.017	0.022	0.019	0.018	0.017	0.021
GHOST	0.021	0.017	0.016	0.021	0.018	0.023	0.020	0.018	0.017	0.021
PRESERVE	0.020	0.016	0.016	0.020	0.017	0.022	0.019	0.017	0.017	0.021
CITY	0.023	0.016	0.016	0.018	0.020	0.025	0.020	0.017	0.015	0.019

Pairwise Interest Points



	1 to 2	1 to 3	1 to 4	2 to 3	2 to 4	3 to 4
BASE	0.026	0.024	0.029	0.026	0.037	0.034
WINE	0.024	0.024	0.029	0.025	0.036	0.033
GHOST	0.025	0.024	0.028	0.025	0.036	0.033
PRESERVE	0.024	0.023	0.028	0.025	0.035	0.033
CITY	0.026	0.024	0.028	0.026	0.037	0.034

Pairwise Interest Points

Figure 33: Pairwise resistance values for each species and each scenario.

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APPENDIX A: GAUGING STATION INFORMATION, PRECIPITATION RECORDS, GROUNDWATER MONITORING WELL DATA, AND WATER BALANCE CALCULATIONS

Flow monitoring stations within the Cuyama Valley are limited and are concentrated in the lower or northwestern reaches of the watershed (Figure A-1). Table A-1 shows the gauging station information for the eleven USGS gauging stations in the Cuyama River Watershed. A large number of the gauging stations are not located on the main reach of the Cuyama River and have a very short monitoring record. Most of these gauging stations have not been monitored since the late 1970's, and only stations 3, 5, 6, and 11 are located on the Cuyama River. The location and short monitoring period of these four monitoring stations makes it very difficult to correlate gauging data with precipitation data for the region and calculate accurate precipitation inflow into the basin.

Table A-1: Water Gauging Stations Located Within the Cuyama River Watershed

Number	Site Number	Site Name	Period of Record	
1	11136400	WAGON RD C NR STAUFFER CA	6/29/1972	9/30/1978
2	11136480	REYES C NR VENTUCOPA CA	7/27/1972	9/30/1978
3	11136500	CUYAMA R NR VENTUCOPA CA	4/1/1945	9/30/1958
4	11136650	ALISO CYN C NR NEW CUYAMA CA	10/1/1963	9/30/1972
5	11136800	CUYAMA R BL BUCKHORN CYN NR SANTA MARIA CA	10/1/1959	11/12/2008
6	11137000	CUYAMA R NR SANTA MARIA CA	10/1/1929	9/30/1962
7	11137400	ALAMO C NR NIPOMO CA	3/1/1959	2/1/1978
8	11137500	ALAMO C NR SANTA MARIA CA	10/1/1943	9/30/1962
9	11137900	HUASNA R NR ARROYO GRANDE CA	6/1/1959	11/12/2008
10	11138000	HUASNA R NR SANTA MARIA CA	10/1/1929	12/31/1961
11	11138100	CUYAMA R BL TWITCHELL DAM CA	10/1/1958	9/30/1983

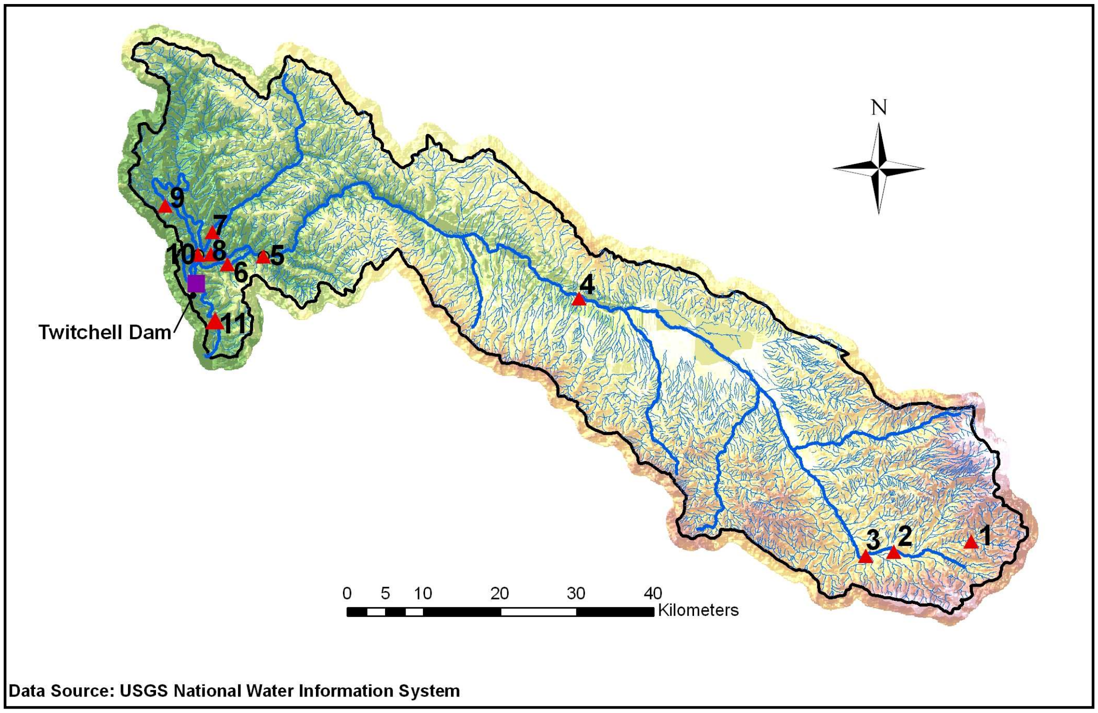


Figure A-1: Water Gauging Station Locations in the Cuyama River Watershed

Table A-2: Data for Active Groundwater Monitoring Wells. Groundwater level (GWL) data for each monitored year can be obtained from the USGS National Water Information System-Groundwater Levels for California

Site Number	Well ID	County	Well Depth	First Monitoring Date	2008 Monitoring Date	First Measurement (Feet Below Land Surface)	2008 Measurement (Feet Below Land Surface)	GWL Change
344910119270501	009N024W33M001S	SB	233	1949-09-00	5/27/2008	152	148.29	-3.71
344944119275701	009N024W32C001S	SB	212	8/12/1942	5/27/2008	74	107.62	33.62
345206119294701	009N025W13B001S	SB	175	1946-00-00	5/27/2008	91	98.99	7.99
345500119343201	010N025W29K002S	SB	450	5/6/1966	4/1/2008	200.7	443.5	242.8
345512119354101	010N025W30F001S	SB	239	8/4/1941	4/1/2008	119.7	166.88	47.18
345540119410901	010N026W20P001S	SB	880	3/30/2001	5/27/2008	138.09	150.89	12.8
345541119384301	010N026W22Q001S	SB	500	4/2/2007	4/1/2008	217.25	176.15	-41.1
345603119411901	010N026W20M001S	SB	790	4/16/1981	5/14/2008	84.62	87.73	3.11
345618119393701	010N026W21A001S	SB	1004	7/10/1976	4/1/2008	128	194.37	66.37
345637119394701	010N026W16Q001S	SB	646	6/15/1950	4/1/2008	165	219.14	54.14
345709119415501	010N026W18F001S	SB	240	8/4/1941	5/14/2008	43.12	122	78.88
345808119433501	010N027W11A001S	SB	215	1/25/1945	5/14/2008	16.39	81.34	64.95
345604119331601	010N025W21G001S	SLO	657	10/2/1946	4/1/2008	77.41	432.86	355.45
345612119313001	010N025W23E001S	SLO	810	10/2/1946	2/15/2008	106	408.81	302.81
345646119350101	010N025W18J002S	SLO	n/a	3/25/1997	4/1/2008	276.96	295.5	18.54
345800119393101	010N026W09H001S	SLO	n/a	4/7/1993	4/1/2008	210.44	305.27	94.83
345822119391801	010N026W04R001S	SLO	238	10/6/1947	4/1/2008	31	164.65	133.65

Agricultural Water Use Calculations: These estimates were only calculated for the current water balance and for the Wine Country scenario because other scenarios result in zero agricultural activity.

Table A-3: Crop acreages and irrigation requirements for 2008. Net Agricultural Pumping was obtained from adding net irrigated and net drip-irrigated pumping requirements

Current Agricultural Water Use							
	Carrots	*Vegetables*	*Alfalfa*	*Orchard*	*Pistachio*	*Vineyard*	*Grain*
Acreage	6,000	4,000	3,000	600	400	215	5,000
Water Requirements (AF/Y)	3	3	5	4	3	3	2
Total Irrigation (AF/Y)	18,000	11,200	15,000	2,280	1,320	602	7,500
Total Irrigated Ag Water Use	**51,700**						
Net Irrigated Ag Water Use (30% Return Flow)	**36,190**						
Total Drip Irrigated Ag Water Use	**4,202**						
Net Drip Irrigated Ag Water Use (0 % Return Flow)	**4,202**						
Net Water Use	**40,392**						

Table A-4: Crop acreages and irrigation requirements for the Wine Country Scenario. Because, the crop types in this scenario use drip-irrigation systems a 0% return flow was assumed to obtain Net Agricultural Pumpage.

Wine Country							
	Carrots	*Vegetables*	*Alfalfa*	*Orchard*	*Pistachio*	*Vineyard*	*Grain*
Acreage	0	0	0	0	400	2145	0
Water Requirements (AF/Y)	3	2.8	5	3.8	3.3	2.8	1.5
Total Irrigation (AF/Y)	0	0	0	0	1320	6006	0
Total Ag Water Use	**7,326**	14.1702128					
Return Flow (0%)	**0**						
Net Water Use	**7,326**	18.1372549					

Municipal and Industrial Use: These estimates were calculated for the current water balance, and for the Wine Country and Satellite City scenarios since water use in the municipal and industrial sector was zero in the remaining scenarios. Table A-5 shows the calculations for determining the amount of water currently being used in both of these sectors. It is important to note that the water use information reported by the USGS in their national water use inventory for both of these sectors was unreliable and based on inconsistent estimates. Therefore, it was best to calculate water use for these sectors as a collective unit.

Because development was limited by the perennial yield of the groundwater basin (approximated at 8,000 AFY), specific water use requirements for the Satellite City Scenario were not calculated. To obtain net water use for this sector, a 40% return flow was taken into consideration and a final net-value of 4,800 AFY was used. The rest of the calculations simply show the amount of people that can be sustained with 8,000 AF of water in a given year (Table A-6, Table A-7)

Table A-5: Calculations to determine the total water currently being used for municipal and industrial purposes.

Current Municipal & Industrial Water Use	
	Municipal & Industrial
GPCD (2000)	215
Population According to 2000 Census	1349
Total Water Use (Gallons/Day)	290035
Gallons/Year	105862775
Gallons in Acres	325,851
AF/Y	324.8804994
M&I, Return Flow (40%)	129.9521998
Net Pumpage (AF/Y)	**195**

Table A-6: Calculations to determine the population that could be sustained with 8,000 AFY in the Satellite City Scenario

Satellite City Scenario Calculations	
Perennial Yield (AF/Y)	8,000
Number of Gallons in an Acre	325,851
Perennial Yield (Gallons/Year)	2,606,811,432
Perennial Yield (Gallons/Day)	7,141,949
Population sustained at 148 gallons/person/day	48,256
Net Water Use with a 40% Return Flow (AF/Y)	4,800

Table A-7: Calculations to determine the number of 20-Acre Vineyards that could be sustained with 8,000 AFY in the Wine Country Scenario

Wine Country Scenario Calculations	
Perennial Yield (AF/Y)	8,000
Water Demand of Wine Production – M&I (AF/Y)	18.59
Irrigation Demand of 20 Vineyard with Drip Irrigation	56
Total Water Demand (AF/Y)	74.59
Total Vineyards at Perennial Yield	107.25
Total M&I Water Use (AF/Y)	1,994
Net M&I Water Use with a 40% Return Flow (AF/Y)	800

Vegetative Water Use

The consumptive use of water by native vegetation in the Cuyama Valley for current conditions, and for the Ghost Town and Nature Preserve scenario are shown in Table A-8, Table A-9, and Table A-10. In the Wine Country and Satellite City Scenario, it was assumed that water use from natural vegetation would not significantly change relative to current conditions. Therefore, the same estimates were used for the water balance calculations in those scenarios. In the Ghost Town scenario, it was assumed that the amount of vegetation relying on groundwater decreased to a little over half of the current value. This represents an estimation made by group members based on the fact that groundwater levels have significantly dropped in that scenario – causing vegetative water consumption to decrease. In the Nature Preserve scenario, it was assumed that restoration efforts on the riparian zone would be taking place and so a modest 10% increase in vegetation acreage was assumed for this scenario.

Table A- 8: Calculations to determine the quantity of water used by native vegetation

Current Estimated Consumptive Use of Water by Native Vegetation			
	Swamp	*Dense Trees, grass, & brush*	*Sparse grass, brush, few trees*
Acreage	0	0	1200
Annual Unit consumptive use less rainfall (Feet)	4.2	4.7	1.2
Estimated annual draft on groundwater (AF)	0	0	1440
TOTAL (AF)	1440		

Table A-9: Calculations to determine the quantity of water used by native vegetation in the Ghost Town scenario

Ghost Town			
	Swamp	*Dense Trees, grass, & brush*	*Sparse grass, brush, few trees*
Acreage	0	0	700
Annual Unit consumptive use less rainfall (Feet)	4.2	4.7	1.2
Estimated annual draft on groundwater (AF)	0	0	840
TOTAL (AF)	840		

Table A-10: Calculations to determine the quantity of water used by native vegetation in the Nature Preserve scenario

Nature Preserve			
	Swamp	*Dense Trees, grass, & brush*	*sparse grass, brush, few trees*
10 % Increase in Acreage	0	120	1320
Annual Unit consumptive use less rainfall (Feet)	4.2	4.7	1.2
Estimated annual draft on groundwater (AF)	0	564	1584
TOTAL (AF)	2148		

APPENDIX B: CIRCUITSCAPE SCENARIO OUTPUT PER SPECIES

<u>Two-striped gartersnake (*Thamnophis hammondii*)</u>

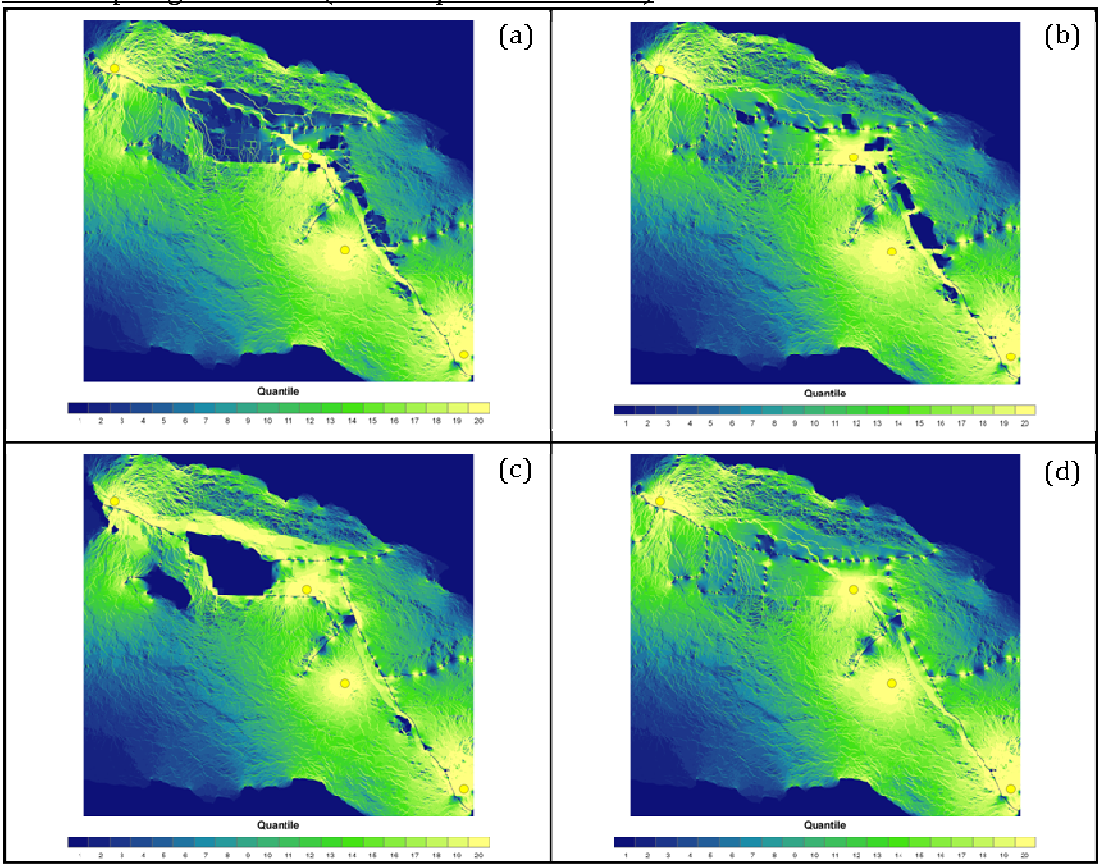
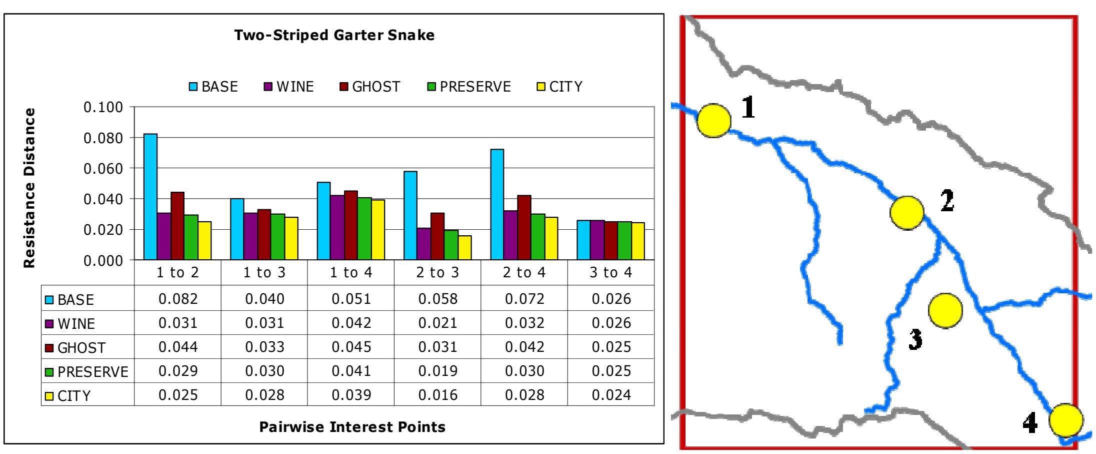


Figure B-1: Circuitscape scenario output for Two-striped gartersnake (a) Ghost Town (b) Wine Country (c) Satellite City (d) Nature Preserve



	1 to 2	1 to 3	1 to 4	2 to 3	2 to 4	3 to 4
BASE	0.082	0.040	0.051	0.058	0.072	0.026
WINE	0.031	0.031	0.042	0.021	0.032	0.026
GHOST	0.044	0.033	0.045	0.031	0.042	0.025
PRESERVE	0.029	0.030	0.041	0.019	0.030	0.025
CITY	0.025	0.028	0.039	0.016	0.028	0.024

Figure B-2: Pairwise resistance values and location of interest points for the Two-striped gartersnake.

Pronghorn antelope (*Antilocapra americana*)

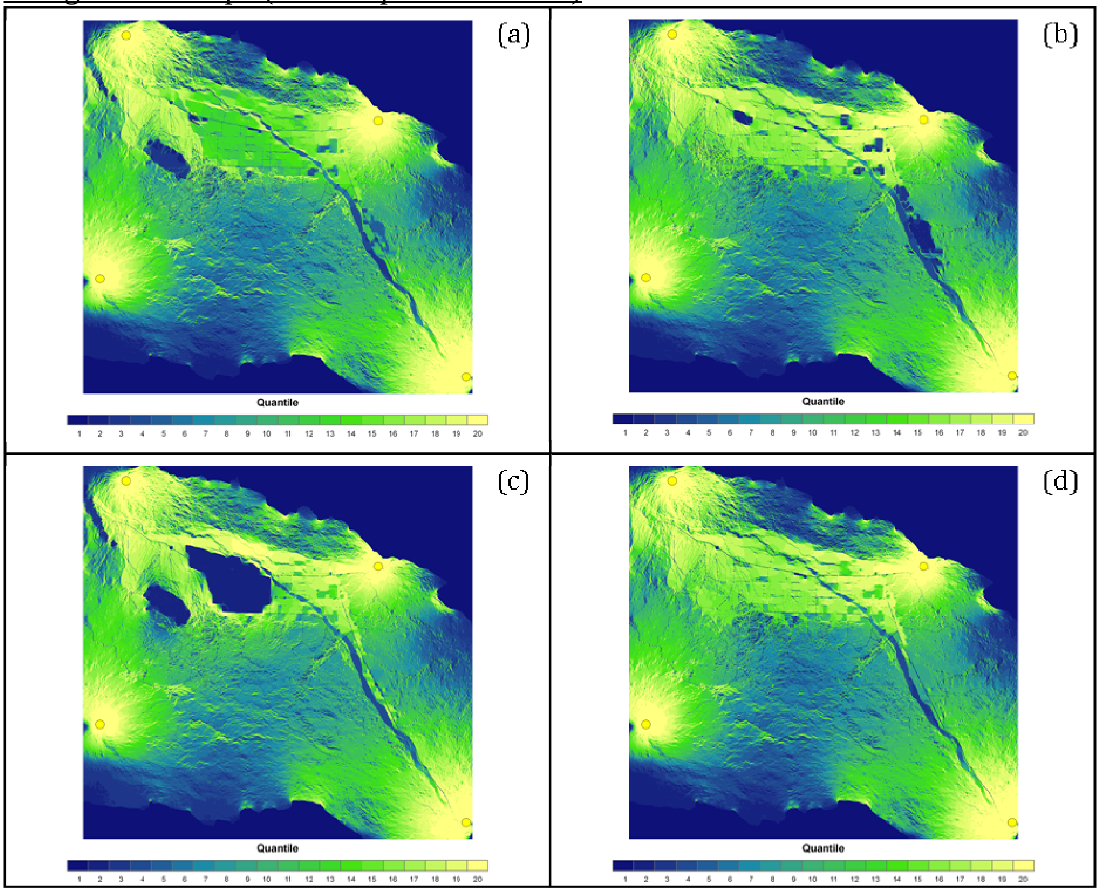
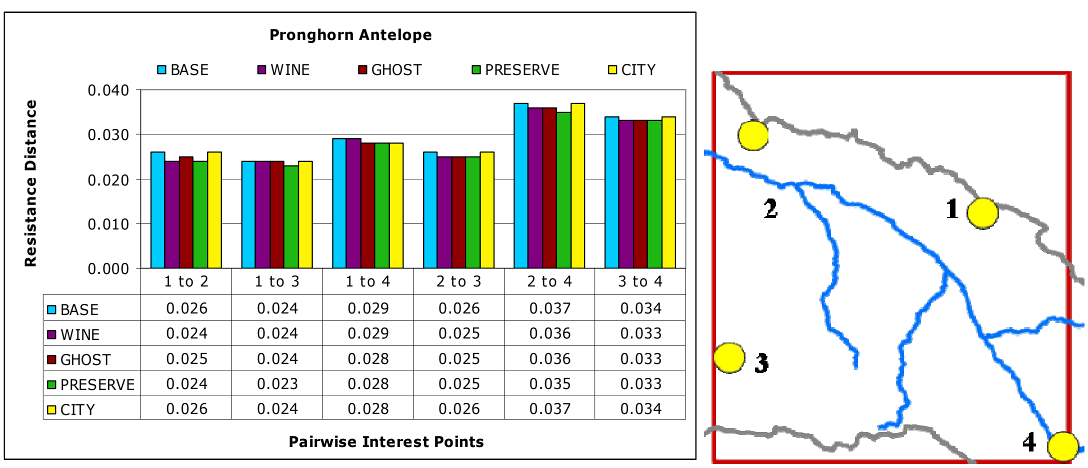


Figure B-3: Circuitscape scenario output for Pronghorn antelope (a) Ghost Town (b) Wine Country (c) Satellite City (d) Nature Preserve



	1 to 2	1 to 3	1 to 4	2 to 3	2 to 4	3 to 4
BASE	0.026	0.024	0.029	0.026	0.037	0.034
WINE	0.024	0.024	0.029	0.025	0.036	0.033
GHOST	0.025	0.024	0.028	0.025	0.036	0.033
PRESERVE	0.024	0.023	0.028	0.025	0.035	0.033
CITY	0.026	0.024	0.028	0.026	0.037	0.034

Figure B-4: Pairwise resistance values and location of interest points.

San Joaquin kit fox (*Vulpes macrotis mutica*)

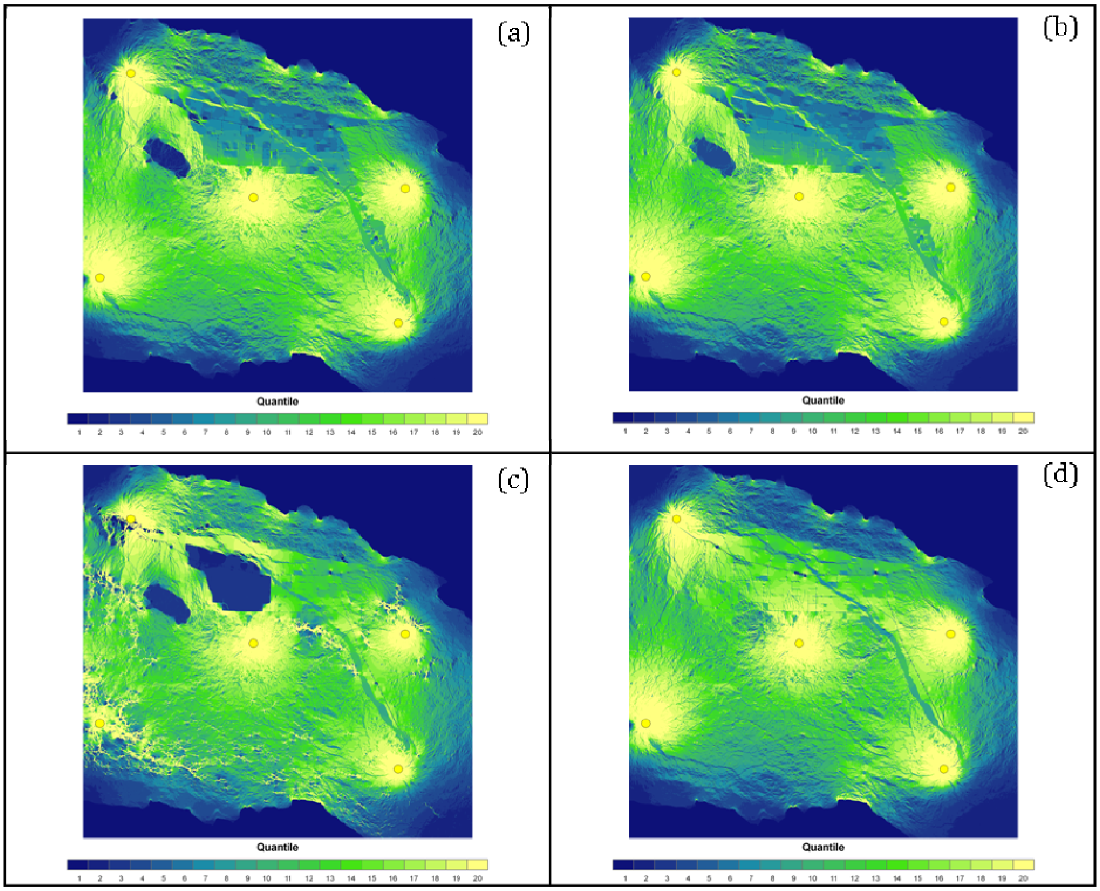
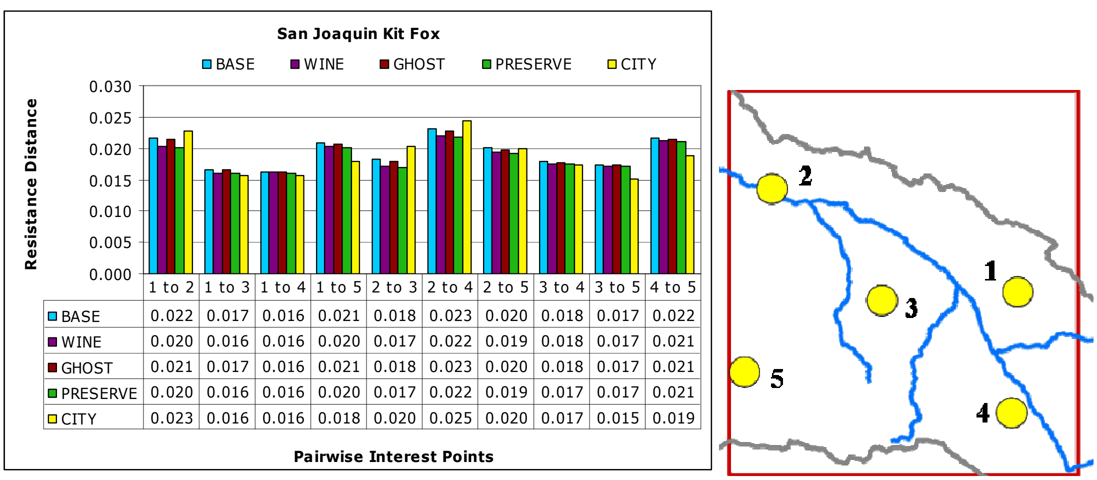


Figure B-5: Circuitscape scenario output for San Joaquin kit fox (a) Ghost Town (b) Wine Country (c) Satellite City (d) Nature Preserve



	1 to 2	1 to 3	1 to 4	1 to 5	2 to 3	2 to 4	2 to 5	3 to 4	3 to 5	4 to 5
BASE	0.022	0.017	0.016	0.021	0.018	0.023	0.020	0.018	0.017	0.022
WINE	0.020	0.016	0.016	0.020	0.017	0.022	0.019	0.018	0.017	0.021
GHOST	0.021	0.017	0.016	0.021	0.018	0.023	0.020	0.018	0.017	0.021
PRESERVE	0.020	0.016	0.016	0.020	0.017	0.022	0.019	0.017	0.017	0.021
CITY	0.023	0.016	0.016	0.018	0.020	0.025	0.020	0.017	0.015	0.019

Figure B-6: Pairwise resistance values and location of interest points.

Blunt-nosed leopard lizard (*Gambelia sila*)

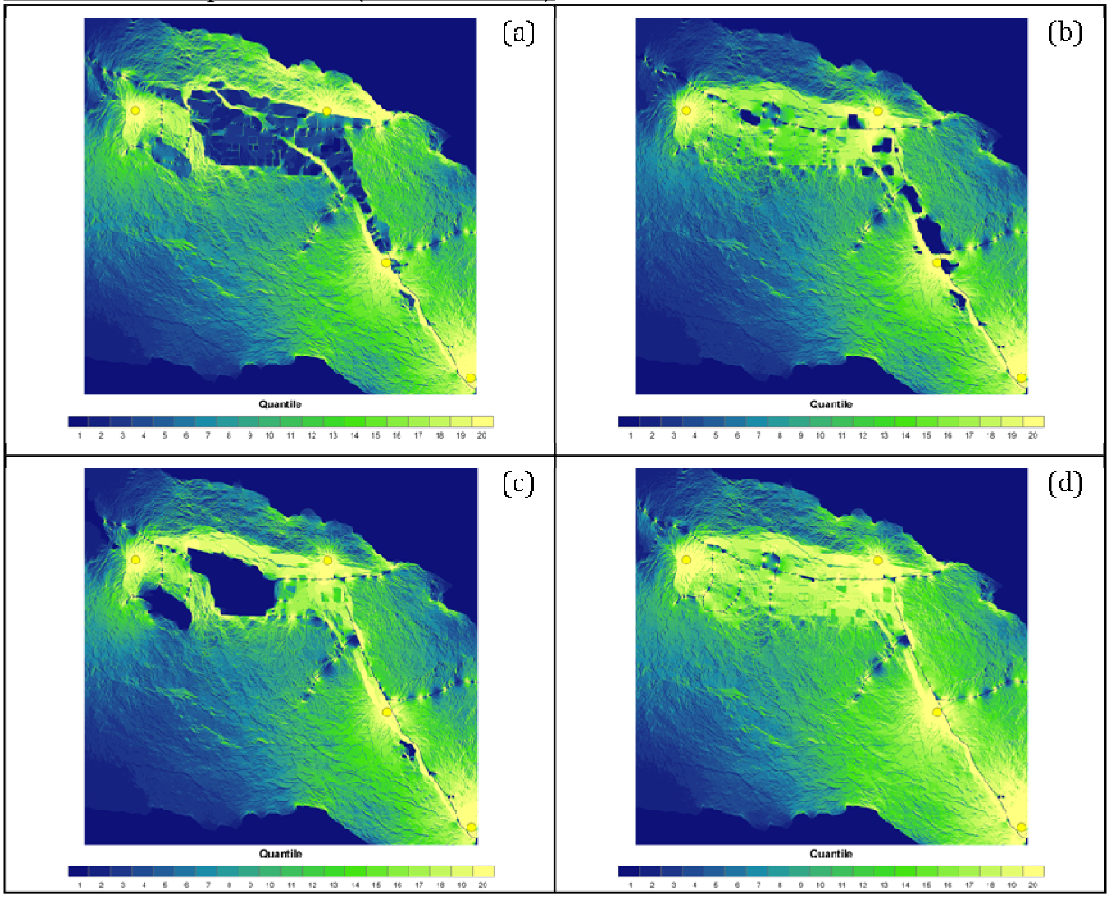
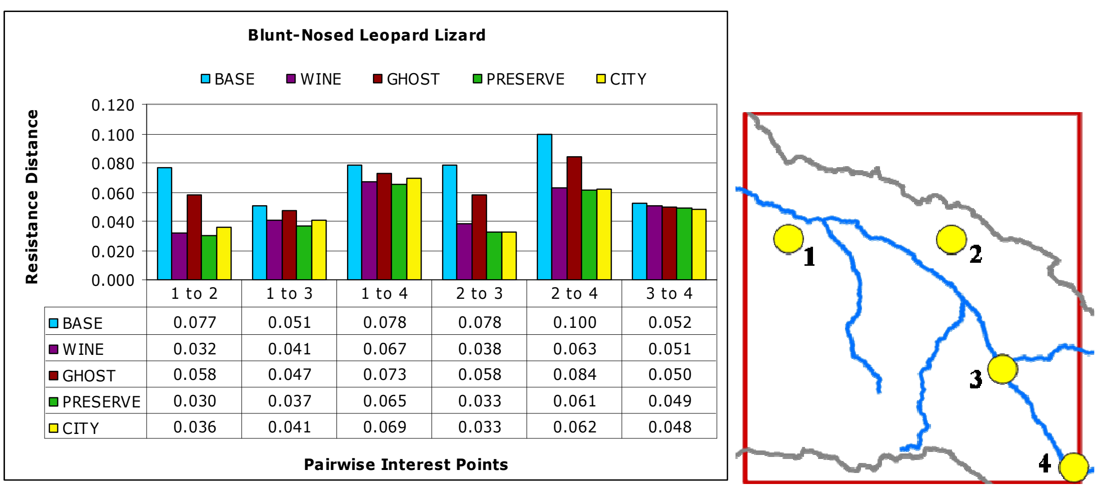


Figure B-7: Circuitscape scenario output for Blunt-nosed leopard lizard (a) Ghost Town (b) Wine Country (c) Satellite City (d) Nature Preserve



	1 to 2	1 to 3	1 to 4	2 to 3	2 to 4	3 to 4
BASE	0.077	0.051	0.078	0.078	0.100	0.052
WINE	0.032	0.041	0.067	0.038	0.063	0.051
GHOST	0.058	0.047	0.073	0.058	0.084	0.050
PRESERVE	0.030	0.037	0.065	0.033	0.061	0.049
CITY	0.036	0.041	0.069	0.033	0.062	0.048

Figure B-8: Pairwise resistance values from Circuitscape scenario output.

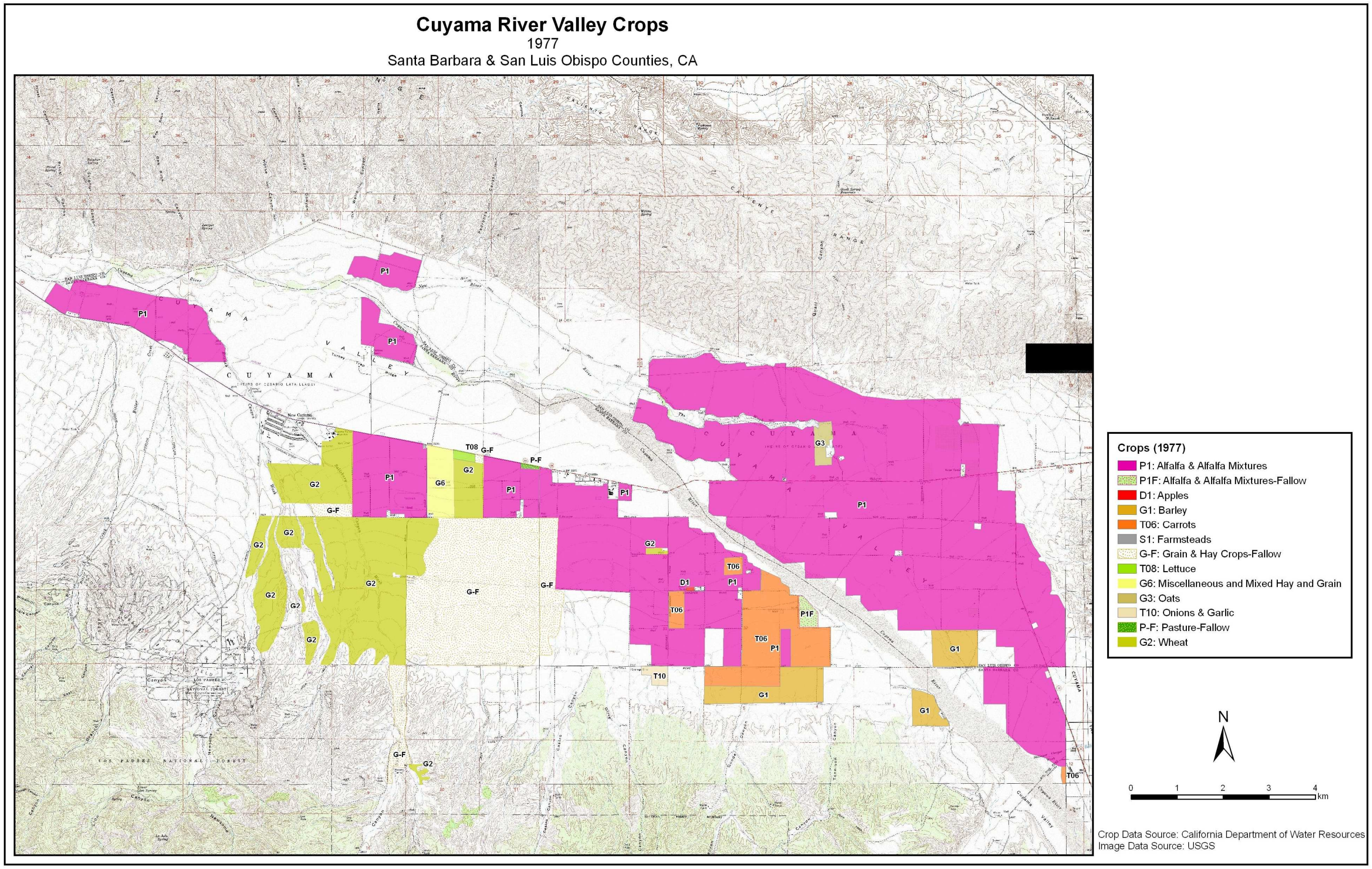


Figure C-1: Cuyama Valley crop types in 1977

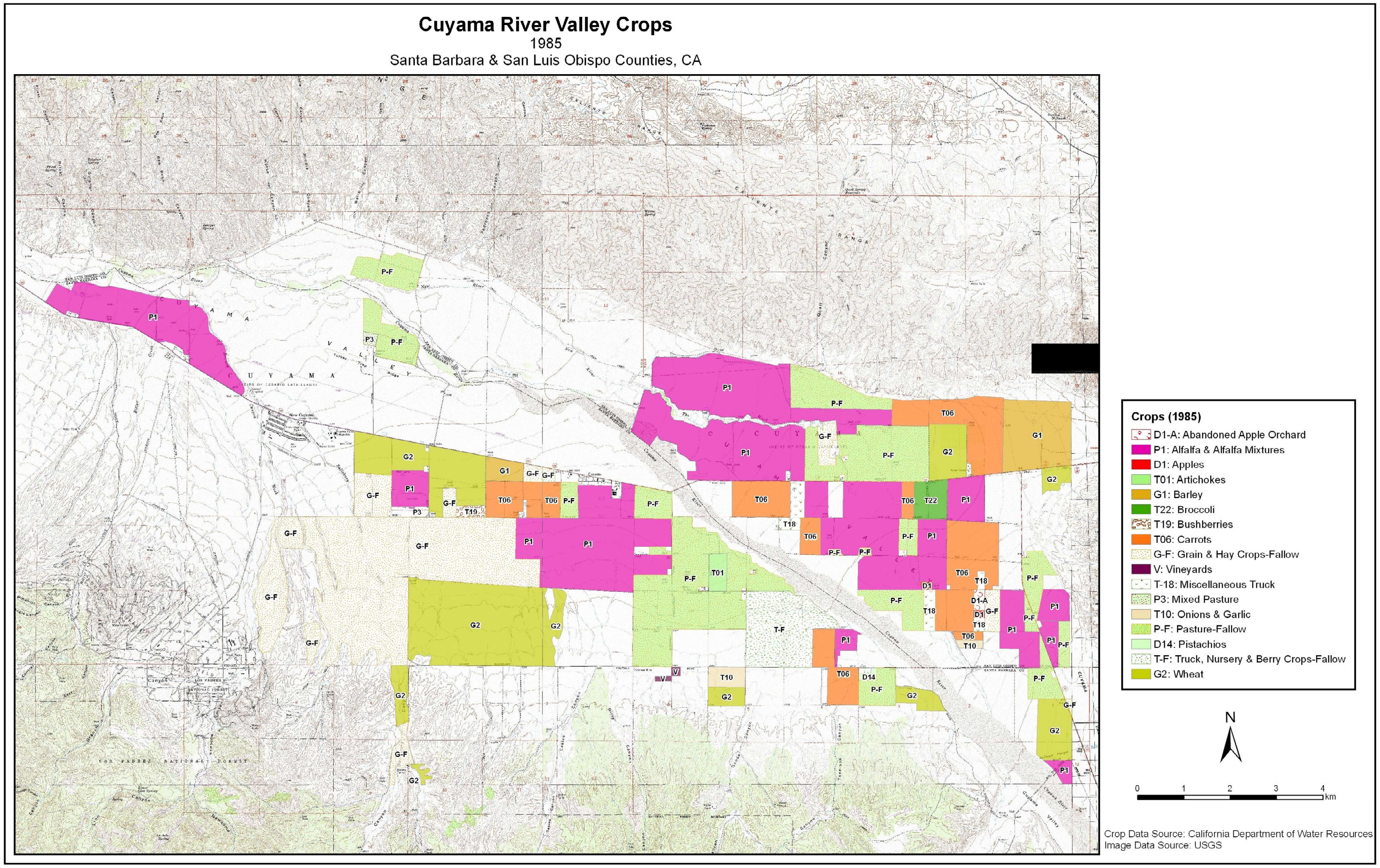


Figure C-2: Cuyama Valley crops in 1985

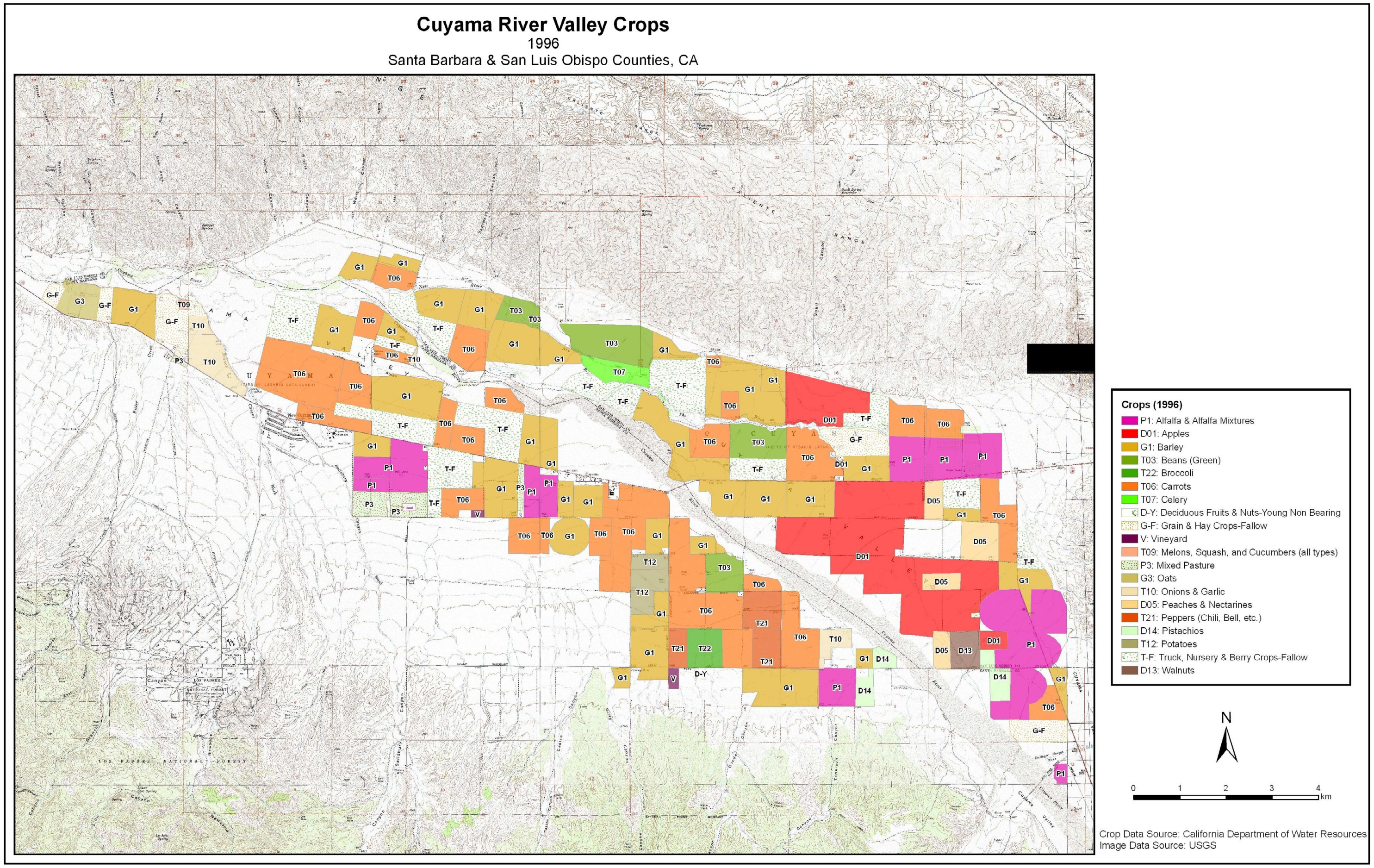


Figure C-3: Cuyama Valley crops in 1996

APPENDIX D: DATA SOURCES FOR FIGURES

Figure 1: Conceptual framework used as a project guide. Model was adapted from Steinitz as cited in Ahern (2006)

- Adapted from Steinitz as cited in Ahern (2006)

Figure 2: Geologic formations found within the Cuyama Valley.

- National Resources Conservation Service, Soil Survey Geographic (SSURGO) Database, Official Soil Series Descriptions-Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. [http://soils.usda.gov/technical/classification/osd/index.html]

Figure 3: Location of the Cuyama Valley in the Central Coast of California.

- California Spatial Information Library [http://casil.ucdavis.edu/casil]
- National Hydrography Dataset [http://nhd.usgs.gov]
- USGS National Map Seamless Server [http://seamless.usgs.gov/index.php]

Figure 4: Land ownership **in the Cuyama Valley.**

- The Nature Conservancy

Figure 5: Current distribution of agricultural crops in the Cuyama Valley.

- Santa Barbara Agricultural Commissioner Pesticide Use Data [http://www.countyofsb.org/agcomm/data.asp]
- San Luis Obispo County Agriculture Commissioner Pesticide Permit Data [http://www.slocounty.ca.gov/Page73.aspx]

Figure 6: Location of the five active gravel mine operations in the Cuyama Valley.

- California Spatial Information Library
- Caltrans Office of GIS [http://www.dot.ca.gov/hq/tsip/gis/datalibrary/gisdatalibrary.html]
- National Hydrography Dataset
- US Department of Interior Bureau of Land Management – California State Office
- USGS National Map Seamless Server

Figure 7: 2002 Aerial image of in-stream mining of aggregate in the Cuyama River.

- Map and Imagery Laboratory, Davidson Library, University of California, Santa Barbara
    - napp-3c_12451-161_2002

Figure 8: Location of oil fields in the Cuyama Valley.

- BASINS
- California Spatial Information Library
- National Hydrography Dataset
- US Department of Interior Bureau of Land Management – California State Office
- USGS National Map Seamless Server

Figure 9: Approximate locations of the nine parcels proposed for oil auction in the Cuyama Valley based on location data provided by the Bureau of Land Management (2006).

- California Spatial Information Library
- National Hydrography Dataset
- US Department of Interior Bureau of Land Management – California State Office
- US Department of the Interior Bureau of Land Management. 2006. Environmental Assessment (EA) for Leasing Certain Parcels within the Bakersfield Office for the June 14, 2006 Oil and Gas Lease Sale. [http://www.lpfw.org/docs/Oil/BLM/0606ea.pdf]
- USGS National Map Seamless Server

Figure 10: Proposed renewable energy resource development sites in Santa Barbara and San Luis Obispo Counties. Yellow squares are solar thermal generating facilities, purple polygons are wind generation sites and the green circle indicates a biomass project. Light grey regions define CREZ locations identified in the RETI resource assessment.

- Black & Veatch Corporation. Renewable Energy Transmission Initiative (RETI) Phase 1B – Resource Report. [http://www.energy.ca.gov/reti/documents/2008-08-16_PHASE_1B_DRAFT_RESOURCE_REPORT.PDF]

Figure 11: Location of the Cuyama Groundwater Basin (light blue) and major tributaries

- California Spatial Information Library
- California Department of Water Resources
- USGS National Map Seamless Server

Figure 12: Depth to groundwater data in feet below land surface for the 17 active groundwater monitoring wells in the Cuyama Valley.

- National Hydrography Dataset
- USGS National Water Information System [http://nwis.waterdata.usgs.gov/ca/nwis/gwlevels?search_criteria=huc_cd&search_criteria=obs_count_nu&submitted_form=introduction]

Figure 13: This well, located in the southeastern portion of the groundwater basin, has experienced a 302 ft. drop in groundwater levels over the past 60 years.

- USGS Water Information System

Figure 14: A drop of approximately 355 feet has occurred in this monitoring well located in the southeastern part of the basin.

- USGS Water Information System

Figure 15: Groundwater level data for a well located near the intersection of Branch Canyon Creek and the Cuyama River.

- USGS Water Information System

Figure 16: Depiction of the distribution of soils where the USGS groundwater monitoring wells are located. Geologic formation descriptions are available in Appendix B.

- USGS Water Information System

Figure 17: Data for a groundwater well near Ventucopa. This well does not experience a significant trend of decline due to groundwater recharge.

- USGS Water Information System

Figure 18: Illustration of potential connectivity pathways in the Cuyama Valley.

- California Spatial Information Library
- National Hydrography Dataset
- USGS National Map Seamless Server
- The Nature Conservancy

Figure 20: Locations of bridge underpasses critical for species movement. Yellow areas represent the top 10% of conductance values.

- Caltrans Office of GIS

Figure 21: Extent of river where phreatophitic (water-loving) vegetation historically occurred.

- National Hydrography Dataset
- US Department of the Interior Bureau of Land Management
- USGS National Map Seamless Server

Figure 22: Illustration of the qualitative comparison of the riparian vegetation.

- Map and Imagery Laboratory, Davidson Library, UCSB
    - napp-3c_12451-101_2002
    - napp_1892-61_1989
    - usda-40-060790-bw_278-116_1978
    - c-5140_6_1938

- National Agriculture Imagery Program [http://165.221.201.14/NAIP.html]
    - 2005 1 meter mosaic data for Santa Barbara County

Figure 23: Placement of transects in 1938 aerial image for riparian analysis.
- Map and Imagery Laboratory, Davidson Library, UCSB
    - c-5140_7_1938

Figure 31: The portion of the valley analyzed for scenario connectivity.
- BASINS
- Caltrans Office of GIS
- Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) [http://www.landfire.gov/index.php]
- National Hydrography Dataset
- US Department of the Interior Bureau of Land Management – California State Office

Figure 33: Pairwise Resistance Values and Location of Interest Points for Modeled Species Across Scenarios
- BASINS

Figure A-1: Water Gauging Station Locations if the Cuyama River Watershed
- USGS Water Information System

Figure B-2: Pairwise Resistance Values and Location of Interest Points for Two-striped Gartersnake
- BASINS

Figure B-4: Pairwise Resistance Values and Location of Interest Points for Pronghorn Antelope
- BASINS

Figure B-6: Pairwise Resistance Values and Location of Interest Points for San Joaquin Kit Fox
- BASINS

Figure B-6: Pairwise Resistance Values and Location of Interest Points for Blunt-nosed Leopard Lizard
- BASINS

Figure C-1: Cuyama Valley Crops in 1977
- California Department of Water Resources Land Use Series, Quads 57-39 and 57-40
- Map and Imagery Laboratory, Davidson Library, University of California, Santa Barbara

Figure C-2: Cuyama Valley Crops in 1985

- California Department of Water Resources Land Use Series, Quads 57-39 and 57-40
- Map and Imagery Laboratory, Davidson Library, University of California, Santa Barbara

Figure C-3: Cuyama Valley Crops in 1996

- California Department of Water Resources Land Use Series, Quads 57-39 and 57-40
- Map and Imagery Laboratory, Davidson Library, University of California, Santa Barbara

APPENDIX E: AERIAL IMAGES FOR RIPARIAN ANALYSIS

2005 mosaic data for Santa Barbara County was obtained from the National Agriculture Imagery Program with the US Department of Agriculture. [http://165.221.201.14/NAIP.html]

The images were courtesy of the Map and Imagery Laboratory, Davidson Library,UCSB. Images are for educational and research purposes only.

Flight	Frame	Year	Flight	Frame	Year
c-5140	2	1938	napp	1882-33	1989
c-5140	3	1938	napp	1883-60	1989
c-5140	4	1938	napp	1883-62	1989
c-5140	5	1938	napp	1883-64	1989
c-5140	6	1938	napp	1883-98	1989
c-5140	7	1938	napp	1884-191	1989
c-5140	10	1938	napp	1892-122	1989
usda-40-06083-cir	178-181	1978	napp	1892-122	1989
usda-40-06083-cir	178-203	1978	napp	1892-132	1989
usda-40-06083-cir	178-205	1978	napp	1892-132	1989
usda-40-06079-bw	278-116	1978	napp	1892-61	1989
usda-40-06083-cir	278-118	1978	napp	1892-88	1989
usda-40-06083-cir	278-120	1978	napp	1892-96	1989
usda-40-06083-cir	278-122	1978	napp-3c	12442-130	2002
usda-40-06083-cir	278-146	1978	napp-3c	12442-132	2002
usda-40-06079-bw	278-148	1978	napp-3c	12442-173	2002
usda-40-06083-cir	278-158	1978	napp-3c	12442-26	2002
usda-40-06083-cir	278-256	1978	napp-3c	12442-270	2002
usda-40-06079-cir	278-59	1978	napp-3c	12442-272	2002
usda-40-06079-cir	278-61	1978	napp-3c	12442-274	2002
usda-40-06079-cir	278-63	1978	napp-3c	12442-35	2002
usda-40-06079-cir	278-87	1978	napp-3c	12451-101	2002
usda-40-06083-cir	278-89	1978	napp-3c	12451-141	2002
usda-40-06083-cir	278-94	1978	napp-3c	12451-161	2002
usda-40-06083-cir	278-96	1978	napp-3c	12451-230	2002
napp	1877-84	1989	napp-3c	12451-30	2002
napp	1877-91	1989	napp-3c	12451-56	2002
napp	1879-130	1989	napp-3c	12454-10	2002
napp	1881-195	1989	napp-3c	12455-120	2002
napp	1881-197	1989	napp-3c	12466-46	2002
napp	1881-61	1989	napp-3c	12466-47	2002
napp	1881-92	1989	napp-3c	12466-48	2002