Promoting Multi-benefit Floodplain Conservation Strategies Along the Lower Santa Clara River Through the Prioritization of Agricultural Conservation Easements

A group project submitted in partial satisfaction of the requirements for the degree Master of Environmental Science & Management

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project 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 Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Robert Wilkinson, Advisor

Abstract

The objective of this project is to prevent the need for additional flood control structures along the Santa Clara River in Ventura County, California. The Santa Clara is one of the last major river systems in Southern California that remains in a relatively natural state. The Nature Conservancy (TNC), who is leading the Natural Floodplain Protection Program (NFPP) along the Santa Clara River, has acquired funding to purchase agricultural conservation easements within the 500-year floodplain to preserve flood control benefits. This project seeks to prioritize parcels for easement acquisition outside of developed areas and within the floodplain. A multi-criteria analysis was developed that incorporates predictions of future structural flood control needs and downstream flood reduction benefits on a parcel-based scale. Two models were used to predict the locations of future development that would necessitate structural flood control. Downstream flood reduction benefits were analyzed using a 2-dimensional hydrological flood model. Additionally, the project outlined several methodologies to estimate the price of agricultural conservation easements in the study region. The results of the development and hydrological analysis were combined to produce parcels organized by ranked tiers. These results are presented in a report of recommendations and are included in a decision guidance tool that includes additional relevant agricultural and ecological information. The ultimate objective of the project is to provide easement acquisition recommendations to TNC and facilitate future acquisition decisions that best achieve the goals of the NFPP through the use of the decision guidance tool.

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Table of Contents

1. Executive Summary

The goal of this project was to preserve the benefits of the natural floodplain along the lower Santa Clara River by preventing the need for further structural flood control, such as levees and channelization. To preserve the floodplain and its associated benefits, agricultural conservation easements were prioritized for purchase by identifying areas with high development pressure and potential downstream flood reduction benefits. Additionally, the project estimated easement values for the study area through several different valuation techniques.

The Santa Clara River originates in the San Gabriel Mountains and runs 116 miles to the City of Ventura, where it flows into the Pacific Ocean. The Santa Clara River watershed lies within Los Angeles and Ventura Counties, with a majority of the upper watershed contained within both the Los Padres and the Angeles National Forests. The river is relatively undeveloped in comparison to the other major rivers in Southern California, which has allowed agriculture along the lower Santa Clara River to remain an important industry for several generations. The future of the river's floodplain and the ecosystem services it provides are threatened by potential urban development and structural flood control. While urban growth management policies such as zoning and urban growth boundaries have been passed in jurisdictions along the river, there is considerable uncertainty as to how effective these policies will be in the long run in preventing development in the floodplain.

Recently, a group of local stakeholders and conservation groups have united their efforts in seeking to conserve the river's natural floodplain benefits. The Floodplain Working Group (FWG), led by The Nature Conservancy (TNC), has implemented the Natural Floodplain Protection Plan (NFPP) with the goal of conserving critical parcels within the 500-year floodplain of the lower Santa Clara River and protecting the ecosystem services the natural floodplain currently provides. TNC plans to purchase agricultural easements within the 500-year floodplain that would prevent future development and preserve current agriculture in the floodplain. Four and a half million dollars has been granted for the initial agricultural easement acquisitions. This project will serve to guide easement acquisition according to the objectives of the NFPP.

The project's region of interest (ROI) includes all land within the Federal Emergency Management Agency's (FEMA) designated 500-year floodplain fringe (i.e. not in the designated floodway) of the Santa Clara River within Ventura County. Furthermore, the ROI excludes areas inside of urban growth boundaries that represent urban areas already developed or planned for development along the river. Individual properties owned by TNC and other conservation groups as well as properties that are already protected by structural flood control were excluded from the ROI. A second ROI was used to separate the three primary tributaries of the lower Santa Clara River, Santa Paula Creek, Sespe Creek, and Piru Creek, from the mainstem of the river.

The prioritization of parcels in the ROI resulted from the analysis of two main factors: development pressure and potential downstream flood reduction benefit. Two development prediction models were used to estimate the development pressure for each parcel in the ROI. The first of these was a weighted overlay analysis (WOA) model which quantified development pressure by utilizing input factors that determine the likelihood of a parcel being developed in the future. Input factors were chosen with the input and consultation of various local government agencies, project stakeholders, and relevant research. The seven inputs of the WOA include countywide zoning/General Plan land use designation, distance to urban growth boundaries, FEMA floodplain designations, major road networks, local road networks, parcel size, and proximity to existing levees. Data was collected to create spatial layers for each input factor that could be uploaded into ESRI's ArcGIS 10.1. Each input factor contained a range of scores between one and four, with the highest scores within an input factor given to those criteria indicating the highest development pressure. Analytical Hierarchy Process (AHP) was used with guidance from the Ventura County Planning Division (VCPD) and Local Agency Formation Commission (LAFCo) to develop weights for each factor in the WOA model to provide a quantitative comparison of influence of each factor on the model relative to one another. Countywide zoning/General Plan land use designation, distance to urban growth boundaries, and parcel size were thought to have the largest influence on potential future development. Using the weights derived through the AHP, a weighted sum was developed from the individual scores of each input layer to produce a final WOA score. These scores were assigned to each parcel allowing parcels to be ranked ordinally. The final product of the WOA analysis was a ranking of all parcels in the ROI based on development pressure.

The second development prediction model used for this project was the SLEUTH model, which was developed by Professor Keith Clarke of the UCSB Geography Department in 1996. Since then, it has been used by various researchers to predict regional development in metropolitan areas worldwide and has been continuously updated. SLEUTH has proven to be an accurate predictor of urban growth across a variety of locations and scenarios. It is a cellular automaton model that uses historical land use change patterns to develop parameters that predict urban growth. SLEUTH is a name derived from its input layers: Slope, Land use, Exclusion, Urban, Transportation, and Hillshade. Historic sets of these input layers are used to calibrate the model's growth parameters, which can then be used to predict urban development to a specified time horizon. Three different future growth policy scenarios were examined using three different Exclusion layers. The values in an Exclusion layer quantify an area's resistance to development. The primary policy scenario used current zoning designations for the Exclusion layer. The two additional scenarios, the Zero and 75 Percent SOAR exclusion scenarios, provide context to the primary scenario by showing both an unconstrained and conservative development scenario respectively. The final results of the SLEUTH model provide probability of development 50 years into the future for each parcel in the ROI.

A hydrology analysis was conducted to identify parcels that could potentially provide downstream flood reduction benefits. Parcels that provide downstream flood reduction benefits were identified in the ROI using output data from the MIKEFLOOD module previously run by cbec, inc. Velocity vectors were used to create a directional magnitude map of a 100-year flood event to identify areas where floodwaters are being diverted from the floodway. Additionally, average parcel volumes and velocities were found using MIKEFLOOD output data.

Using this data, parcels were identified that divert floodwaters from the flow of the river's mainstem, slow the magnitude of the floodwaters, and serve as temporary storage of floodwaters during flood events. Only parcels that could divert, slow, and hold floodwaters were selected in the hydrology analysis.

Results from the WOA model were combined with parcels identified in the hydrology analysis as providing downstream flood reduction benefits to tier parcels in the ROI. Tier one consists of parcels with WOA final scores greater than the median that were selected in the hydrology analysis as providing potential downstream flood reduction benefits. Tier two consists of parcels with WOA final scores greater than the median but not selected in the hydrology analysis. Tier three consisted of parcels selected in the hydrology analysis with WOA scores below the median. Lastly, tier four includes parcels not selected in the hydrology analysis and WOA scores below the median. In a similar way, results from the SLEUTH model were combined with parcels selected in the hydrology analysis to tier parcels. Tier structure was arranged similarly to that of the WOA tiers, using a SLEUTH development probability of 30 percent or greater as a threshold to divide parcels. This resulted in tier one consisting of those parcels with a development probability of 30 percent or greater that were also selected in the hydrology analysis.

The parcels found in both tier one results were labeled as top priority parcels. This grouping represents parcels with the highest development pressure and the greatest potential for downstream flood reduction benefits. It is recommended that initial easement acquisition effort be focused on these 18 parcels. The tier one parcels from each development model are the second recommended focus for easement acquisition.

Agricultural easement values were also investigated in this project. Agricultural conservation easements have not been used in this region before, meaning that there is no standard price for them. This made it necessary to evaluate different appraisal methodologies to better understand what a fair market price for easements might be. Four appraisal methodologies were used including income capitalization, sales comparison, similar easement comparison, and discounting the value of the development right.

Recognizing that other factors that are not easily added to a prioritization model may influence TNC's easement acquisition strategies, a decision guidance database/tool was developed. The database contains results from both models and additional potentially relevant information for each parcel that may assist TNC with future acquisition. Additional information includes agricultural and ecological characteristics of each parcel and alignment with other TNC conservation priorities in the ROI. The results and framework of this project will help guide TNC to use the allotted funds most effectively in their goal of conserving the floodplain.

2. Project Objectives

I. Prioritize parcels for the purchase of agricultural conservation easements in the 500-year floodplain of the lower Santa Clara River that will best achieve the objectives of the Floodplain Working Group. These objectives include maintaining the extent of natural floodplain through the avoidance of further structural flood control while preserving its ability to attenuate downstream flooding.

II. Create a decision guidance tool that includes parcel characteristics beyond those used for prioritization to aid The Nature Conservancy in purchasing easements into the future.

III. Develop methodologies to determine a fair market price for agricultural easements in Ventura County and provide a range of estimates according to these methodologies.

3. Project Significance

Natural floodplains are those that are unrestricted by flood control structures, such as levees, dams, or river channelization and are free from intensive uses such as industrial, commercial, or residential development. They are important because of the multitude of ecosystem services they provide to nature and society (Gren et al., 1995).

Ecosystem services that natural floodplains provide include downstream flood control, ground water recharge, important habitat for aquatic and riparian species, and fertile land for farming. As natural floodplains are lost, their ability to provide these ecosystem services is severely reduced and communities are forced to spend financial resources to make up for their loss.

Beyond the financial and social costs from losing ecosystem services, building in and constricting natural floodplains can also lead to increased flood risk to those communities built in the floodplain. Property owners can suffer high financial losses resulting from large-scale flooding events. Because of continued construction in floodplains and the failure of flood control structures, average yearly flooding damage has increased, from $41 million/year in the 1960’s to $378 million/year in the 1990’s (adjusted for inflation) (Brody et al., 2011). If development is restricted from natural floodplains, the risk of failing flood control structures is decreased and the extreme financial loss associated with these failures are significantly reduced.

There is reason enough to maintain natural floodplains without the uncertainty that a changing climate introduces in predicting future precipitation patterns and flood heights. Scientists have been unable to come to a consensus about what future precipitations patterns will look like, especially at local scales. Because of this uncertainty, it is prudent to ensure these systems remain resilient to minimize social costs under future rainfall and flood scenarios. Maintaining the natural floodplain will provide this resilience without requiring costly structural flood control.

The lower Santa Clara River located in Ventura County, California serves as an example of the importance of preserving natural floodplains. The lower Santa Clara River is one of the few remaining natural floodplains left in Southern California and provides many important services to the county. These services include downstream flood control to the communities of Ventura and Oxnard, habitat for 16 threatened or endangered species, and economically and culturally important farmland. These floodplain functions are at risk from increasing urban encroachment into the floodplain. In recognition of these threats and the considerable value of the natural floodplain, a group of stakeholders comprised of The Nature Conservancy (TNC), the Ventura County Watershed Protection District (VCWPD), the Farm Bureau, the Resource Conservation District, and the Natural Resources Conservation Service have come together to create the Floodplain Working Group. Their mission is to preserve the Santa Clara River’s natural floodplain and the functions it provides to the surrounding areas by implementing the Natural Floodplain Protection Plan (NFPP).

As a part of this working group, the VCWPD completed a study in 2011 which valued the current floodplain benefits. The rough estimates in the study found that the 500-year floodplain provides $1.05 billion in downstream flood control during a 500-year flood event and $204 million during a 100-year flood event. Partially as a result of this finding, the Floodplain Working Group was awarded a grant from the Integrated Regional Watershed Management Program (IRWMP) through Proposition 84 to preserve the natural floodplain of the lower Santa Clara River. The IRWMP grant specified the purchase of agricultural conservation easements in the floodplain as the method of preservation. These easements will preserve many services associated with the natural floodplain such as flood control and high-value agriculture.

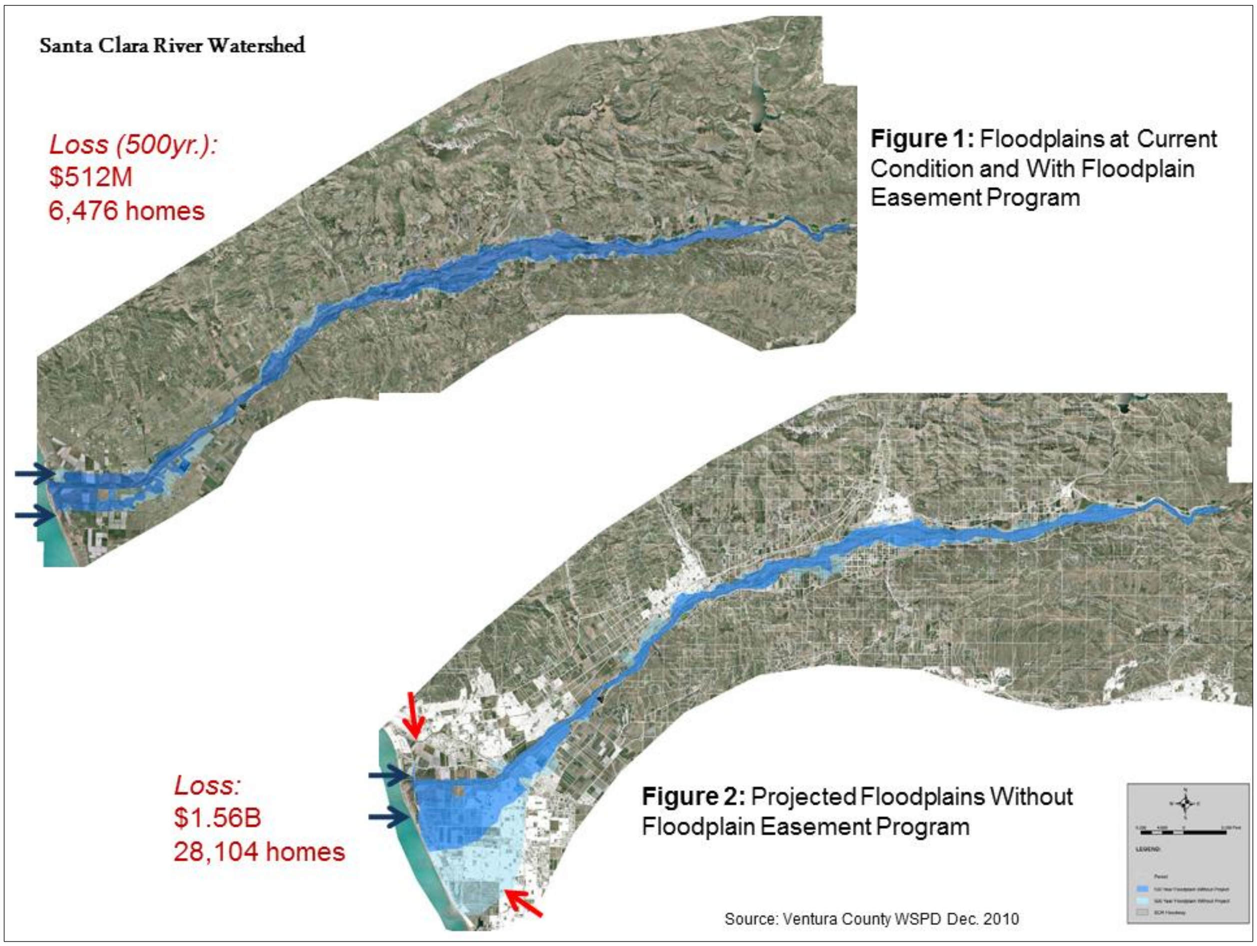

Figure 3.1: Different Scenarios based on with or without Floodplain Easement Program (Source: VCWPD 2010)

In order to most effectively and efficiently use the IRWMP grant funds, agricultural parcels must be prioritized for easement acquisition based upon their contributions to maintaining current extent and function of the SCR floodplain. Additionally, because agricultural conservation easements have not been used in Ventura County prior to this project, there is no current accepted market value for easements. The goal of this project is to prioritize these parcels and determine the value of easements for acquisition by TNC and the Floodplain Working Group.

4. Background on the Santa Clara River and Ventura County

The Santa Clara River originates in the San Gabriel Mountains and runs 116 miles to the City of Ventura, where it flows into the Pacific Ocean. The Santa Clara River watershed lies within Los Angeles and Ventura Counties, with a majority of the upper watershed contained within both the Los Padres and the Angeles National Forests. The river is relatively undeveloped in comparison to the other major rivers in Southern California. Additionally, agriculture along the lower Santa Clara River has historically been, and continues to be, an important industry for Ventura County. The future of the river and the ecosystem services it provides are threatened by potential future urban development and the resulting levee protections that would surround these developments.

4.1 Santa Clara River Background

The Santa Clara River is one of the last major rivers in Southern California that has avoided channelization, extensive development, and major loss of ecosystem functions. Other Southern California rivers, such as the Los Angeles and Santa Ana Rivers, have had their channels and banks paved with concrete and include major levee systems to manage flood risk to the extensive adjacent development. The Santa Clara River Watershed drains an area of approximately 1,626 square miles, making it one of the largest watersheds on the Southern California coast. It changes in elevation from sea level at the coast to 2,692 m (8,832 feet) in the San Gabriel Mountains (Stillwater Sciences, 2007) (Figure 4.1). The San Gabriel Mountains border the watershed to the east, and the Santa Ynez Mountains and Tehachapi Mountains to the north. The river is managed by multiple agencies including the State Department of Water Resources through the State Water Project (Piru and Castaic reservoirs), the State Water Resources Control Board, the Ventura County Watershed Protection District, and the Federal Emergency Management Administration (FEMA). In addition, Sespe Creek, a tributary to the Santa Clara River is designated as a National Wild and Scenic River. The National Wild and Scenic River Program is administered and necessitates coordination among a myriad of federal agencies including the Bureau of Reclamation, US Forest Service, US Fish and Wildlife Service, and the National Parks Service (Interagency Wild and Scenic Rivers Coordinating Council, 1999).

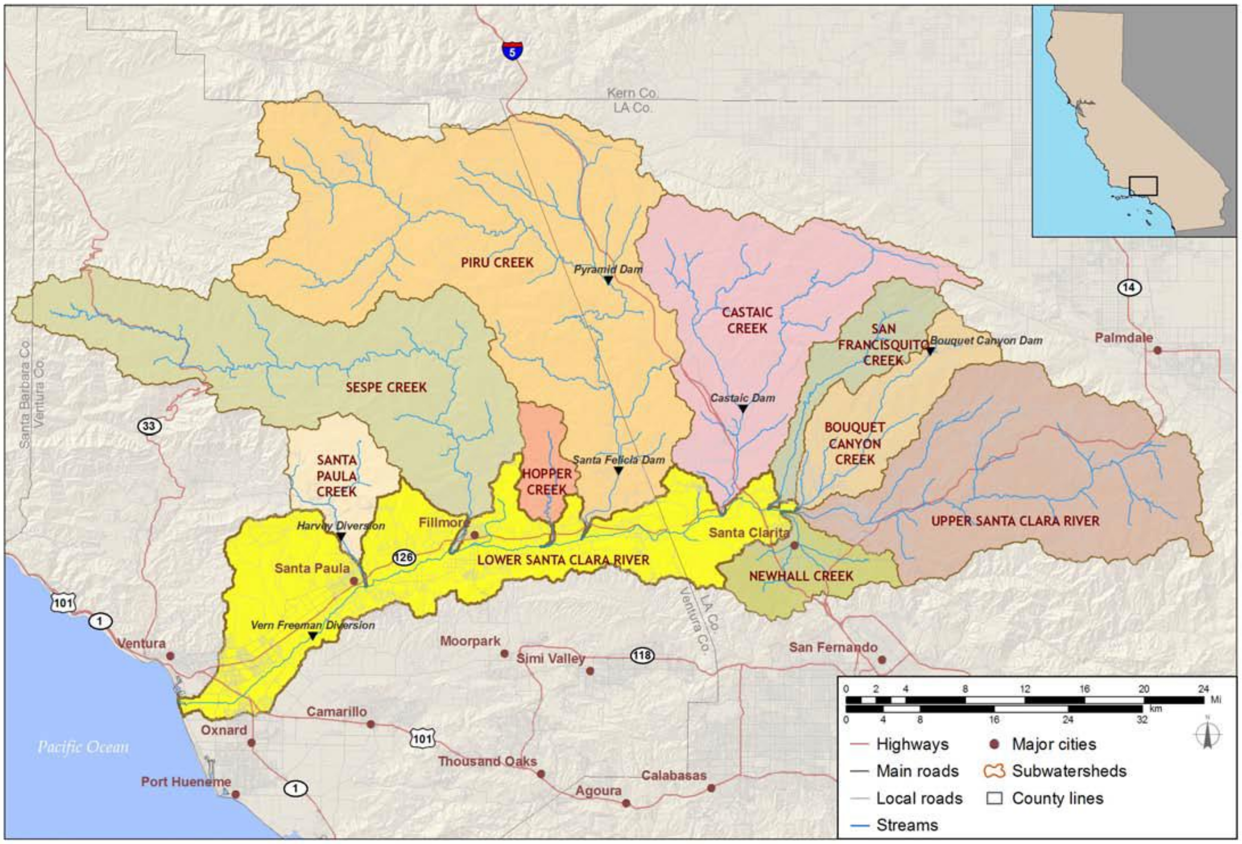

Figure 4.1: Santa Clara River Watershed (Source: Stillwater Sciences, 2008)

Tributaries

Tributaries of the Santa Clara River include Santa Paula, Sespe, Hopper, Piru, Castaic, San Francisquito, and Bouquet Canyon Creeks (See Figure 4.1). Approximately 85% of the flow that exits the mouth of the Santa Clara River comes from a combination of these tributaries and the upper Santa Clara River (URS, 2005). Numerous barrancas (small, generally incised tributary streams) and ephemeral creeks make up the remaining 15% of river flow. The flow regime in the tributaries is similar to the main river course, remaining relatively small except during high-intensity, short-duration storm events (Stillwater Sciences, 2008). Piru and Castaic Creeks are supplied in part by the State Water Project and store water in reservoirs behind the Santa Felicia and Castaic Dams respectively. The Bouquet Canyon Dam and reservoir provide water to the Los Angeles Aqueduct System (Barker, 1987).

Levees

Since the 1950's when major levee construction first began in Ventura County, there has been a progressive increase in the extent of bank protection along the Santa Clara River. As of 2005, 33% of the total length of the Santa Clara River has some form of bank protection (URS, 2005). Levees, a form of bank protection, act to confine high discharges and significantly reduce the width of the river during large flood events. Additionally, levees are vulnerable to damage and scour during repeated large flood events (*e.g.*, January and February 1969; January and

February 2005). Recently, the perception of levees has changed and their apparent disadvantages have made the construction of new levees less desirable. This is partly because of the large expense involved in continued levee maintenance, and partly because of their negative impacts on natural river systems. During flooding events, these impacts include unnatural alignment in the river course, increased scour and erosion on opposite unprotected banks, and increased chance of bed erosion. When floods recede, these impacts result in increased sediment deposition. Additionally, it has been found that levees increase the rates of channel incision because of increased velocities and scouring rates (Stillwater Sciences, 2007). Along the Santa Clara River, the net effect of levees is channel bed incision, which is made worse by channel knickpoint development initially caused by historic aggregate mining (Stillwater Sciences, 2007).

An example of the costly nature of levee maintenance is the decertification of Levee Santa Clara River-1 (SCR-1) by the Army Corps of Engineers in 2009. Certification entails the Army Corps of Engineers or some other qualified engineer concluding that there is less than a one percent chance in any year that a flood will break through or wash over a levee. The SCR-1 Levee System is approximately 4.72 miles long and is located along the southeast bank of the Santa Clara River between Highway (Hwy) 101 and Saticoy in the City of Oxnard. The estimated cost of rehabilitation work required for recertification is $45 million (Wenner, 2011). Because of the high costs of recertification, the required work has not yet been conducted and these levees remain decertified (ACOE, 2012).

Regulatory Water Authority

The Ventura County Watershed Protection District (VCWPD), an independent management district that oversees watershed planning and management within Ventura County, has jurisdiction over the Santa Clara River Watershed in Ventura County. VCWPD is administered by its Board of Supervisors and oversees the implementation of county ordinances governing the protection and regulation of flood control facilities and watercourses. The VCWPD also administers floodplain management on behalf of Ventura County to ensure compliance with the National Flood Insurance Program. This includes permit review authority for structures and other developments built within or that include identified floodplains. For incorporated jurisdictions, each city designates a floodplain manager for its sphere of influence. Cities with floodplain jurisdiction over the Santa Clara River are Ventura, Oxnard, Santa Paula, and Fillmore (VCWPD, 2011).

Historical Flooding in Ventura County and Monetary Loss Values

Floods in California are a relatively frequent occurrence and can produce large scale and costly damages. In Northern California, the New Year’s Day Flood of 1997 resulted in levee failures in Olivehurst, Arboga, Wilton, Manteca, and Modesto (SFACA ,2012). Damages from this flood totaled $35 million dollars. During the same period, levee overtopping and breaks occurred in the Sacramento River Basin resulting in $2 billion in damages to over 23,000 homes and businesses, agricultural lands, bridges, roads, and flood infrastructure (USGS, 1998).

According to the Flood Mitigation Plan and Risk Assessment conducted for Ventura County in 2005, flooding in Ventura County has been reported as early as 1862 and damaging floods have occurred about every five years since then (URS, 2005). The largest and most damaging recorded natural flood in the Santa Clara and Ventura watersheds occurred in 1969. The City of Oxnard was threatened by potential levee failures, and the 50- and 100-year flood levels were reached in many channels (URS, 2005). As a result of the 1969 flood events, 13 deaths occurred and property damage was estimated at $60 million (1969 dollars) (URS, 2005). Another notable flood occurred in 2005 in which the Santa Paula Airport incurred over $6 million in damages (Stowel, 2005) (See Figure 4.2).

Figure 4.2: Santa Paula Airport After 2005 Flood (Source: TNC)

4.2 Agriculture in Ventura County

Summary

The agricultural industry in Ventura County is one of the most prosperous in the state and country. The temperate Mediterranean climate allows for high value crops to be grown, such as avocados, citrus, and berries. This prosperous agricultural industry is located along the Santa Clara River, specifically, between the main urban centers along the river's mainstem (See Figure 4.3).

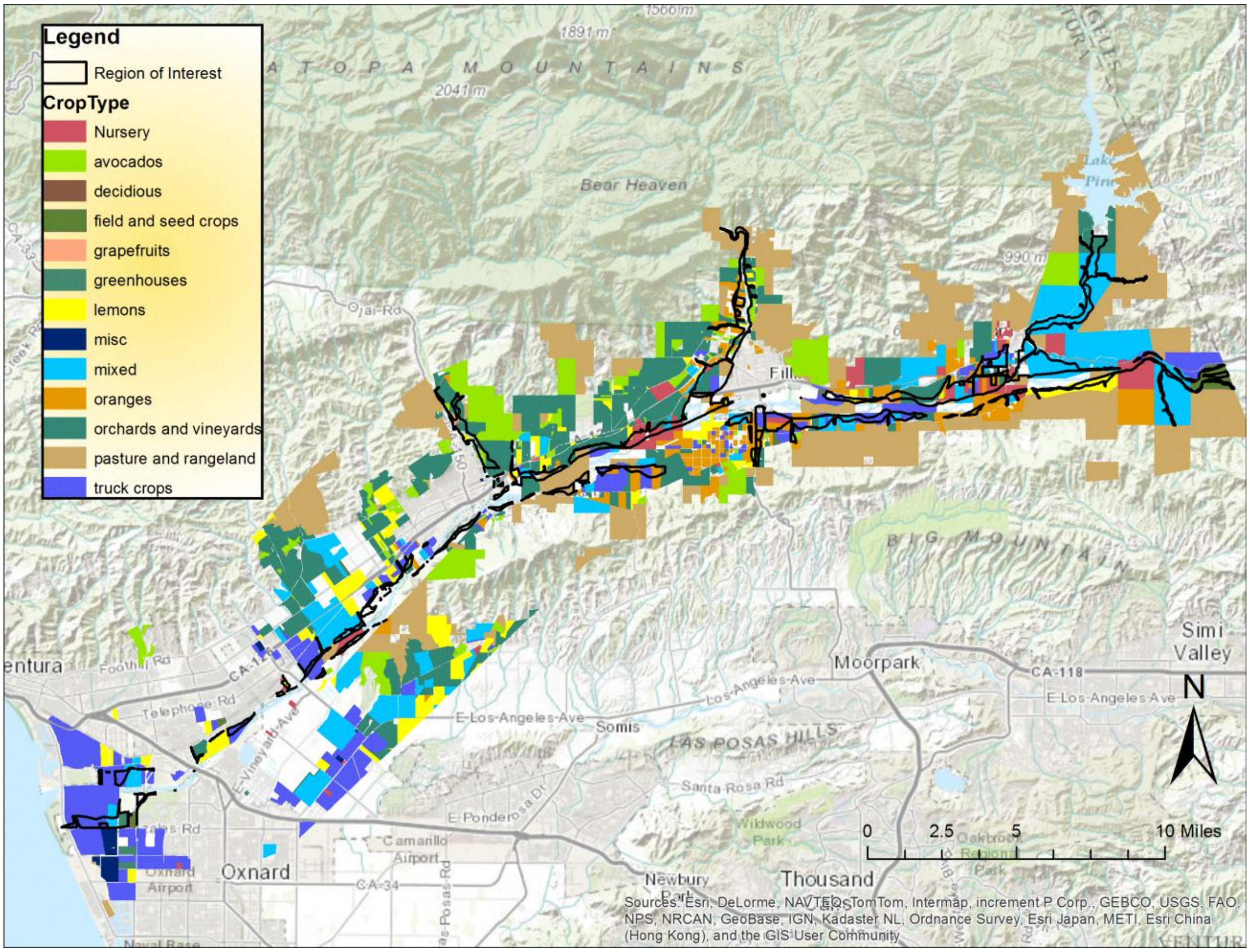

Figure 4.3: Crop Type along Lower Santa Clara River

Threats to Agriculture

Ventura County's unique microclimate and rich soils make the value of its agricultural production one of the highest in the nation. In the 2007 USDA Census of Agriculture Report, Ventura ranked 4th in the nation in terms of total value of crops sold (USDA, 2007). This ranking highlights the importance of agriculture to the economy of Ventura; 2005 estimates have shown agriculture providing 31,000 jobs and about $2.133 billion in economic value (Kembara et al., 2008). In 2011, the gross value of Ventura County's agricultural crops was $1.84 billion (Ventura County Crop Report, 2011).

Despite the high value of agriculture in this area and farmland preservation ordinances (e.g. Save Open-space and Agricultural Resources (SOAR) ordinances, Land Conservation Act, etc.), the threat of development is still high due to its proximity to Los Angeles (60 miles), expansive coastline, and scenic foothills (VCALT, 1996). While cities and the County can try to prevent sprawl by using policy tools such as the Guidelines for Orderly Development (GOD) and SOAR, they still need to accommodate a rising population which is projected to grow 25% in Ventura County between 2010 and 2050 (CA DOF, 2012). According to some sources, infill is unlikely to be sufficient to handle this population growth by itself (Fulton et al., 2001). The City of Santa

Paula provides an example of how sprawl reducing policy tools can be overcome in favor of development into agricultural lands. Only six years after first passing the SOAR initiative, the city voted to extend their City Urban Restriction Boundary (CURB) boundaries (a city's SOAR boundary) to include 6,500 more acres. This was done again in 2008 to include an additional 1,500 acres. These annexations highlight the high rate of farmland conversion to development and the need for stronger protection. Despite farmland preservation efforts between 1984 and 2008, 7.5% of important farmland was lost in Ventura County, much of which is in the SCR Valley (See Figure 4.4; FMMP, 2012).

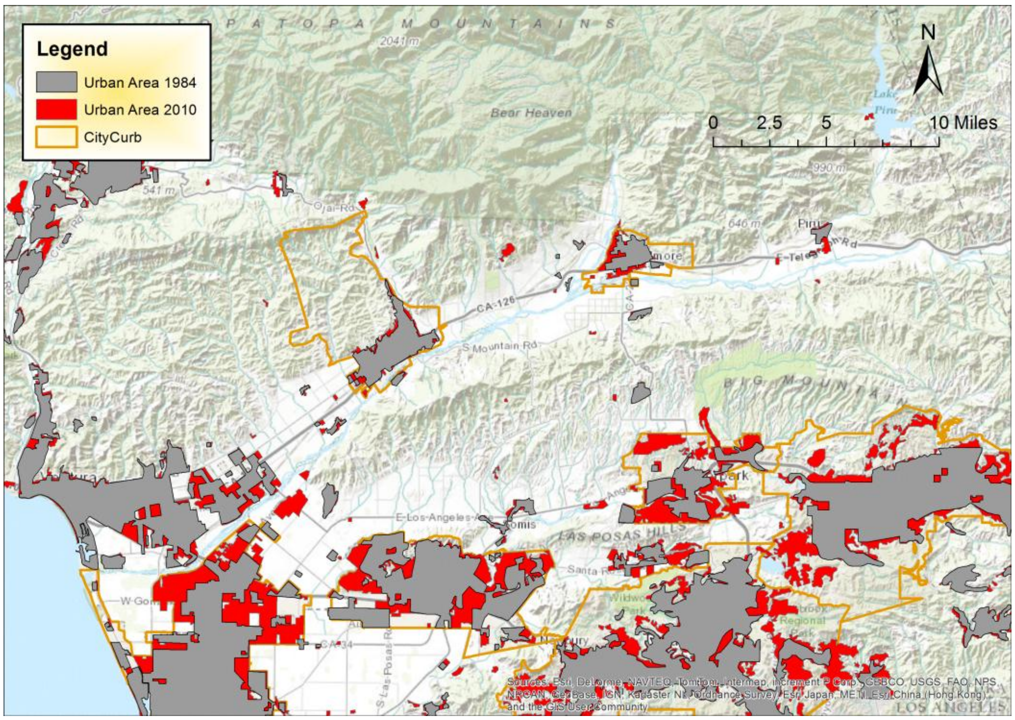

Figure 4.4: Expansion of urban areas in Ventura County since 1984 is shown in red. Most recent SOAR CURB boundaries are shown in orange.

4.3 Urban Growth and Land-Use Policies

Two of the major urban growth policies in Ventura County are the Guidelines for Orderly Development (GOD) and the Save Open-space and Agricultural Resources (SOAR) initiative. GOD is the framework used by the County and its cities to collaborate in planning urban development projects. The guidelines encourage urban development within incorporated cities whenever possible (County of Ventura, 2009a).

SOAR is a voter-passed initiative meant to encourage smart growth within the County and its Cities by establishing urban growth boundaries. First implemented in the City of Ventura in 1995, the main goal of the SOAR initiative is to keep urban development within clearly defined City Urban Restriction Boundary (CURB) delineations and to prevent sprawl outside those boundaries. This is accomplished by requiring any development or rezoning of lands outside the CURB delineation to be authorized by voters. The SOAR initiative has been passed by

Ventura County and 8 of its 10 cities, including the three major cities along the Santa Clara River: Santa Paula, Fillmore, and Ventura. This means that in order for a city to change its CURB delineations, it must be approved by voters of that city; additionally, rezoning of farmland in the county must be approved by a countywide ballot (SOAR, 2008).

While SOAR has been successful in many respects, it has some limitations in its ability to preserve open space and farmland. First, it has no way of addressing the threat of ranchettes. Rachettes are individual 10-acre farms are bought as a single parcel and converted from farmland to residential use without triggering SOAR. Second, expansion of SOAR boundaries can be and has been approved by voters. In Santa Paula, for example, two major ballot initiatives to expand CURB delineations have resulted in 8,000 acres being added to city limits for major housing developments. Finally, the SOAR initiatives throughout Ventura County will begin to expire in 2020, after which reauthorization by voters must be procured to continue protection (SOAR, 2008).

There are two major land-use policies in Ventura County whose purposes are to protect farmland and open space: the Land Conservation Act (LCA), also known as the Williamson Act, and Greenbelt agreements. The LCA, or Williamson Act, gives farmers tax breaks in exchange for keeping their land in agricultural production. Farmers enter a self-renewing contract for a period of at least 10 years. This means that a contract is always in its first year unless non-renewal of the contract is initiated at which point there would be 9 years left of the contract. In 2008, Ventura County had 128,900 acres in LCA, with a large portion of that near the Santa Clara River (County of Ventura 2009b).

Greenbelt agreements are made between the county board of supervisors and individual cities in Ventura County. These agreements encourage "greenbelts" between cities by preventing them from annexing property within a greenbelt. Additionally, they force the county to restrict development to uses consistent with existing zoning. Greenbelt agreements exist along the Santa Clara River between the following cities: Ventura-Santa Paula, Santa Paula-Fillmore, and Fillmore-Piru (County of Ventura, 2010). While both LCA and Greenbelts discourage development between the cities along the lower Santa Clara River, they both have inherent limitations that prevent complete protection in perpetuity of agricultural lands from urban sprawl.

4.4 Conservation Status of the Watershed

Since the Santa Clara River is one of the last unchannelized, relatively natural rivers in Southern California, the watershed has been targeted for conservation by many organizations. The watershed is home to over 117 endangered, threatened, or sensitive floral and faunal species (South Coast Wildlands, 2010). Most of the river's watershed is contained within the Los Padres National Forest, the Angeles National Forest, and the San Gabriel Mountains. Conservation efforts have been focused on the linkages between these managed areas, as well as the river itself.

The California State Coastal Conservancy and US Fish and Wildlife Service (USFWS) together developed the Santa Clara River Enhancement and Management Plan (SCREMP). SCREMP, driven by a diverse group of stakeholders and interest groups, served to guide the preservation and management of the river's 500-year floodplain. SCREMP has released recommendations on a variety of floodplain-related topics from public outreach to invasive species removal. With help from local agencies, many of SCREMP's recommendations have been implemented (Stillwater Sciences, 2008).

Another major conservation project headed by the California State Coastal Conservancy is the Santa Clara Parkway Project (SCP). For this project the Coastal Conservancy partnered with The Nature Conservancy (TNC), Friends of the Santa Clara and a group of local stakeholders to conserve and restore the riparian and aquatic habitats of the River while also providing enhanced floodplain protection (The Santa Clara River parkway). The Santa Clara River Parkway Floodplain Restoration Feasibility Study was created by Stillwater Sciences (2007 & 2008) to help aid the Coastal Conservancy and its partners in achieving their floodplain conservation goals. The Feasibility Study highlights a variety of conservation strategies such as invasive species removal, land acquisition, levee removal, and revegetation.

Along with the Coastal Conservancy, TNC has been heavily involved in conservation initiatives along the Santa Clara River and its watershed. Conserving the Santa Clara River watershed is the primary focus of TNC's LA/Ventura project. At the time of this project, TNC had already purchased approximately 3,000 acres along the river (Department of Water Resources [DWR], 2011).

Several documents have aided TNC's conservation objectives for the Santa Clara River. A study from the Bren School of Environmental Science & Management (2000) examined endangered and threatened species habitat along the river and prioritized parcels for land acquisition using funds from the ARCO spill settlement (Court et al., 2000). In 2006, TNC published the Upper Watershed Conservation Plan (UWCP) for the SCR. In the UWCP, TNC highlighted the most important conservation targets, strategies, and threats in the upper watershed. Conservation targets included six diverse vegetation communities, aquatic vertebrates, and terrestrial vertebrates. Land acquisition, invasive species removal, and land-use planning are emphasized in the UWCP as conservation strategies that best fit the Upper Watershed. These strategies were chosen based on their ability to conserve the identified conservation targets (The Nature Conservancy [TNC], 2006). Following the 2006 UWCP, TNC published the Conservation Plan for the Lower Santa Clara River Watershed and Surrounding Areas (LWCP) that also highlights important conservation targets and strategies (TNC, 2008).

As highlighted in the UWCP and LWC, TNC's main strategy for conservation along the Santa Clara River includes land acquisition and land-use planning. The Natural Floodplain Protection Project (NFPP) is the next stage in TNC's Santa Clara River Conservation initiative.

5. Literature Review

In order to design the methodological framework for this project, a literature review has highlighted the basics of agricultural conservation easements, valuation of ecosystem services, and ways of achieving multiple objectives within conservation prioritization projects.

5.1 Agricultural Conservation Easements

Description

Agricultural Conservation Easements (ACEs) are increasingly being used throughout the United States to protect areas where farmland is being lost to intensifying development pressures. An ACE purchases the development rights of a property, which allows farmers to supplement their income while lowering their tax burdens. Beyond their primary objective of farmland preservation, ACE's have also been used to reinforce local planning targets by establishing greenbelts around cities while providing open-space and wildlife corridors to satisfy conservation objectives (Daniels & Lapping, 2005, Lynch & Lovell, 2002, Sokolow et al., 2003). Since they first started being used in the 1970's, ACE's have preserved more than 1.8 million acres in the United States and that number is rising rapidly as state and federal funding programs continue to increase (Sokolow et al., 2003).

Valuation

Traditional appraisal methods value properties based on their associated bundle of rights, future income, and structural improvements. For agricultural properties specifically, the property value is composed of the right to develop the property in the future along with a discounted stream of future agricultural rents associated with the property (Weibe et al., 1996):

$$Fair\ Market\ Value = Development\ Value + Agricultural\ Value$$

Fundamentally, the price of an ACE must compensate the property owner for the development value that the easement is removing. It must also be equal to, or less than, the social value of removing that development right (Weibe et al., 1996).

In theory, a property will only be developed when the future stream of rents associated with development is greater than the future stream of agricultural rents. Determining when this shift in value will happen, along with the value of the development rents, is essential to assessing the "development value" (i.e. the future rents that can be associated with development). Unfortunately, predicting the time of the shift and the quantity of future rents involves a high degree of uncertainty, making a straightforward appraisal method difficult to implement (Weibe et al., 1996).

A common way to circumvent the uncertainty involved in predicting development value has been to subtract the value of agriculture from the fair market value of the property. The resulting value is the market predicted development value:

$$Development\ Rights = Fair\ Market\ Value - Agricultural\ Value$$

While there is less uncertainty using this approach, determining fair market value and agricultural value at local scales can be difficult when land turnover is low as is the case in Ventura County. To overcome this challenge, there have been a few studies that have attempted to standardize easement valuation using econometric and hedonic modeling (Plantinga & Miller, 2001; Lynch & Lovell, 2002). Because of the large variation in agricultural value and development pressure across the United States, these studies remain specific to their study areas, but have uncovered general characteristics that guide easement valuation. Overall, distance to metropolitan areas, local population trends, and lot size, are all shown to significantly affect the value of development rights (Plantinga & Miller, 2001; Lynch & Lovell, 2002). These studies emphasize the site specificity of easement valuation and the necessity of including these characteristics in the valuation approach.

Ventura County

In 1996, a study was published by the University of California and the Hansen Agricultural Trust that looked at the economic value of agriculture in Ventura County. It found, among other things, that agricultural land prices were increasing faster than what would be expected from increasing agricultural production alone, and that, despite the high value of agriculture in the county, farmers were finding it hard to compete against land speculation for expanding cities (Brand et al. 1996). It also found that there was a significant increase in price for properties closer to the urban fringe and lands not enrolled in Land Conservation Act contracts. For example, in 1994, within those areas zoned “Agricultural Exclusive (AE)”, properties adjacent to the urban fringe were valued 25% higher than those further from the urban fringe. These price differentials reflect a difference in development values and illustrate the pressure to develop farmland in Ventura County.

Hoping to preserve farmland by reducing development pressure around cities, Ventura County and the majority of its incorporated cities passed the Save Our Open Spaces and Agricultural Resources (SOAR) initiative in 1995. A study in 2008, published by the Hansen Agricultural Trust, examined the effects SOAR had on the development values associated with agricultural properties in Ventura County. It concluded that SOAR did not remove the development value of properties and therefore did not affect the property value of the land (Kembara et al. 2008).

While it is certain that there is development value associated with agricultural properties in Ventura County, there have been no direct purchases of ACEs as of March 2013. Because of this, there is no accepted value for ACEs for the Santa Clara River floodplain or anywhere else in the County.

5.2 Ecosystem Services in the SCR Floodplain

Ecosystem services are increasingly being used to quantify the free benefits or “natural capital” that are provided to society from intact functioning ecosystems. These benefits include, but are not limited to, the production of food and fiber, carbon sequestration, aesthetic values, provision of clean water, and flood regulation (Daily, 1997). Globally, the provision of ecosystem services has been estimated to be worth $33 trillion every year (Costanza et al., 1997). While there is no doubt that they are important contributors to local economies, attempting to quantify their absolute contribution at a local scale can be difficult because of the global nature of some services, like carbon sequestration, and a lack of data about how local systems work. Additionally, accurately quantifying the non-market values these services provide can be a substantial challenge.

The Santa Clara River floodplain in Ventura County is the source of many such ecosystem services. It provides fertile soils for high value agricultural production, generating over $2 billion annually for the local economy (Kembara et al., 2008). Additionally, it provides open space and recreational values to local residents, permeable surfaces for groundwater recharge, and friendly corridors for a wide range of wildlife species. In 2011, the Watershed Protection District investigated the value of the SCR floodplain to natural flood control. It estimated that preventing further restriction of the natural floodplain would result in the following downstream flood control benefits, assuming no additional flood control-based restriction and land use change in the future (VCWPD, 2011):

Flood event	Anticipated reduction in flood damages
50-year	$21 million
100-year	$204 million
500-year	$1.048 billion

While many ecosystem services, like recreational and aesthetic value, are difficult to measure, the work done by the Watershed Protection District has allowed decision makers to at least partially quantify the value of protecting the Santa Clara River floodplain in its current condition. It is clear that maintaining the natural floodplain is far less expensive than the loss of natural capital that would result from restricting its extent through structural flood control.

5.3 Multiple Objectives in Conservation

Incorporating multi-criteria decision making in prioritizing areas for conservation can effectively maximize project objectives. Preserving farmland through agricultural conservation easements along the Santa Clara River provides multiple benefits to local agriculture, surrounding communities in the floodplain, and Ventura County's financial resources. Research was conducted to identify ways to most effectively capture these benefits in Ventura County for this study.

The study titled, *Prioritizing Farmland Preservation Cost-Effectively for Multiple Objectives* (Machado et al., 2006) approached farmland preservation using multi-criteria decision-making and was used as a resource for the analysis conducted along the Santa Clara River. Machado et al. identified three primary objectives for farmland preservation that are measured quantitatively at each site. To find the overall social value of each site, a weighted summation decision rule was used to incorporate measured scores at each site. Additionally, Machado et al. identified how preserving farmland adjacent to urban growth boundaries can act as a deterrent for urban sprawl. Placing conservation areas next to urban growth boundaries strengthens governmental spatial planning and can act as an additional urban growth management tool in areas threatened by development (Machado et al., 2006).

Another influential study by Stoms et al. looked at the location and effectiveness of agricultural conservation easements in the San Francisco Bay Area as a growth management tools. The study found little evidence of easements being used to reinforce urban growth boundaries and restrict growth, and recommended strategic targeting of agricultural easements as a way to effectively minimize low density sprawl and preserve natural resources surrounding urban areas (Stoms et al., 2006).

These two papers support the analysis conducted in this study. They show how using multi-criteria decision analysis to prioritize conservation easements can act as a strong growth management tool and restrict urban sprawl. Additionally, the methodology used in the Machado et al. paper served as a model for the structure of the weighted overlay analysis conducted in this project along the Santa Clara River in Ventura.

6. Methodology

In order to achieve the objectives of this project, several methodologies were used to provide The Nature Conservancy (TNC) with the most useful tool for easement acquisition. With guidance from TNC and the Ventura County Watershed Protection District (VCWPD), two criteria were determined to be most important in prioritizing easements for acquisition: (1) development pressure and (2) downstream flood benefit.

The first of these criteria, development pressure, was chosen because developing within the 100-year floodplain of the Santa Clara River requires building structural flood control to protect development from damage during flooding events. In order to achieve the project's objective of preventing additional structural flood control and constriction of the natural floodplain, areas threatened by development were identified. To quantify development pressure, two methods were used: a weighted overlay analysis (WOA) and the SLEUTH urban growth model. The second criterion chosen to guide easement acquisition was the ability to reduce downstream flooding. To identify parcels with potential downstream flood reduction benefits, a hydrological analysis was conducted using 2-D flood modeling outputs from the MIKEFLOOD module. Flood reduction benefits were defined in this project as parcels that redirect floodwaters away from the mainstem of the river, thus diverting some quantity of water out of the floodway and reducing the total volume of water traveling down the system. Development pressure and hydrological benefit were analyzed on a per parcel basis.

Prioritization results were provided to TNC as a set of tiered parcels by combining the results of each development pressure analysis with the hydrological analysis. Additionally, a comprehensive decision guidance tool was created for TNC that incorporates development pressure and hydrological analyses results as well as characteristics not captured by these analyses. Finally, to estimate easement costs, several value analyses were conducted for the study area using data on land and crop values.

Region of Interest

The region of interest (ROI) for the project was the FEMA designated 500-year floodplain of the Santa Clara River within Ventura County (See Figure 6.1). The FEMA designated floodway was removed from the ROI because development is not permitted there. Urban areas outside county SOAR jurisdiction and inside cities' urban restriction boundaries (CURB) were excluded from our analysis because local governments plan to utilize these lands for future urban uses. In addition, parcels that are already owned in fee title for the purposes of habitat conservation and open space preservation were removed from the ROI. Finally, parcels with existing levees on them or those located behind existing levees were omitted from the ROI.

Hydrologic data as well as floodway delineations were not available for the main tributaries of the river; as a result, the tributaries were separated from the Santa Clara River and two ROIs resulted. The Santa Clara River ROI includes parcels within the floodplain of the river's mainstem while the tributaries ROI includes parcels along the three major tributaries of the Lower Santa Clara River: Santa Paula Creek, Sespe Creek, and Piru Creek.

Unit of Analysis

Parcels were chosen as the appropriate unit of analysis for the project. Because parcels occur both within and outside of the 500-floodplain and the FEMA designated floodway, parcels in the ROI have been clipped to include only the portion of a parcel within the 500-year floodplain and outside of the floodway. This aligns with TNC's plan of placing easements on the portions of parcels within the 500-year floodplain that meet floodplain protection objectives. All parcel data was obtained from the Ventura County Assessor's roll.

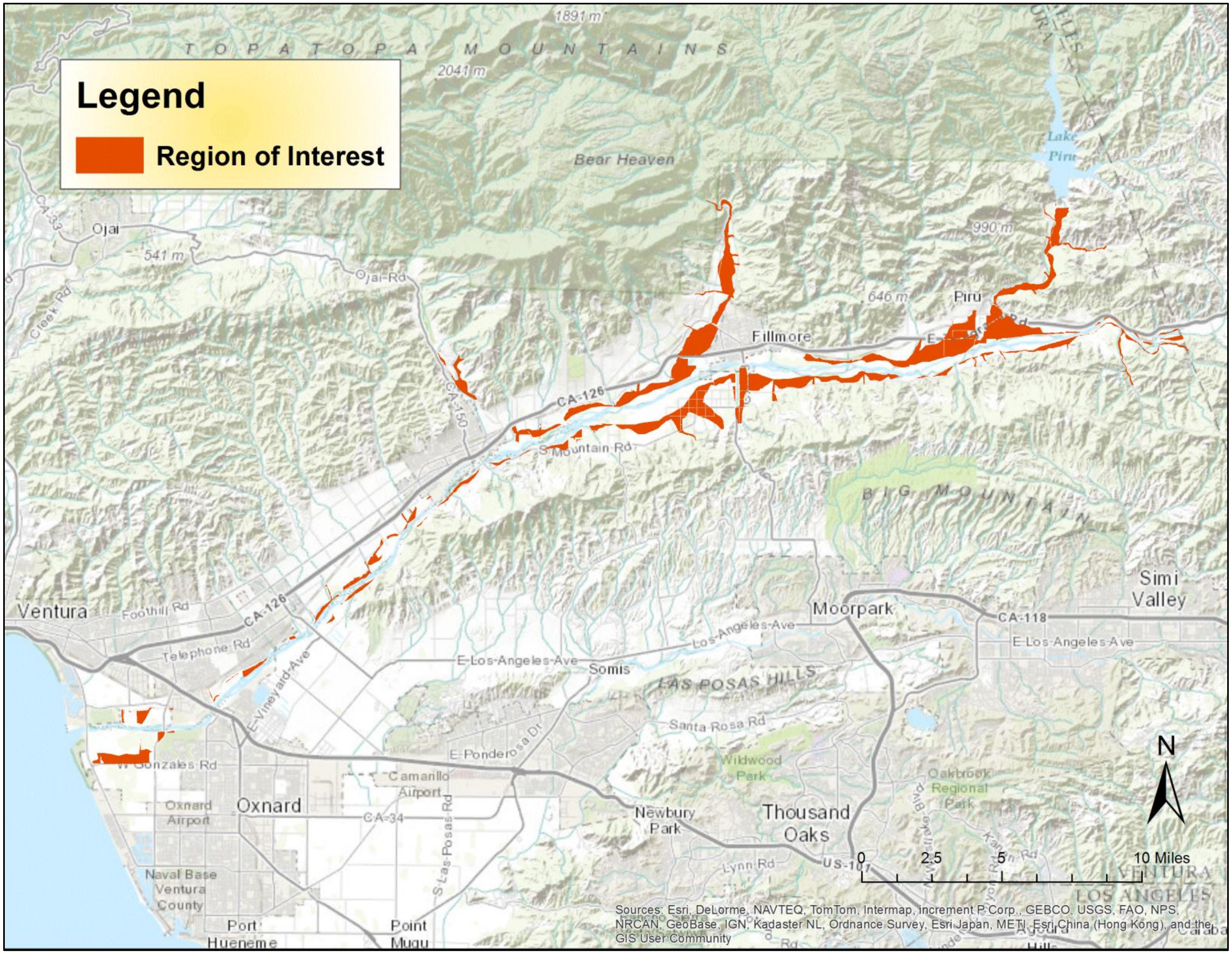

Figure 6.1: Region of Interest for this project's analyses

6.1 Weighted Overlay Analysis

A weighted overlay analysis (WOA) was created to incorporate multiple input factors and rank parcels based on their development pressure. WOA models use modeling programs to weight and overlay multiple spatial layers that produce a comparable metric for different units of analysis. They are used to solve multicriteria problems such as site selection and suitability. The WOA model in this project was built using ModelBuilder in ArcMap 10.1. Seven input factors were used to give parcels a final WOA score. The attributes for each input factor were given a score ranging from "1" to "4", "1" having the smallest significance and "4" having the highest significance. This scoring approach is similar to the system outlined in "The Five-S Framework for Site Conservation" (TNC, 2003), which TNC uses for many of its conservation prioritization projects.

Consultation with TNC, VCWPD, and the Ventura County Planning Division (VCPD) led to the selection of the seven input factors used in the WOA model. These factors include county level zoning and county General Plan land use designations, parcel size, 500- and 100-year floodplain designations, levee tie-in capability, and distance to transportation networks (major and local roads), and urban growth boundaries.

The floodways of Santa Paula Creek, Sespe Creek, and Piru Creek are not currently defined by a regulatory authority. Because of this, WOA results for these tributaries include the floodway in parcel size, even though these areas are not legally developable. This inclusion influenced model results by favoring large parcels that occupy the floodway. Delineating the floodway for these tributaries would strengthen WOA results for the tributaries, better identify and rank parcels in the ROI, and allow for a more accurate comparison of parcels along the mainstem and tributaries. Partly because these floodway designations do not exist, the tributaries were analyzed separately in the WOA model.

Input Factors used in the Weighted Overlay Analysis

County Zoning and General Plan Land Use Designation

Countywide zoning and General Plan land use designations for Ventura County were used in the WOA model. Within the ROI, parcels were zoned Agriculture Exclusive, Open Space, Rural Agriculture, or Rural Exclusive (See Figure 6.2). Zoning designations have requirements for minimum parcel size and types of land use. Table 3.1 shows zoning type and minimum lot area for zones in the ROI. Each zoning designation differs in respect to land use restrictions and minimum lot size, which makes some parcels more easily developable than others. For example, rural exclusive is easier to develop than agricultural exclusive it has more allowable uses and a smaller minimum lot size. Because of this, rural exclusive was identified as having higher development pressure compared to agricultural exclusive in the WOA model. Additional information on County zoning is available in Table 6.15.

Table 6.1: County zoning designations occurring in the ROI

Abbr.	Zone	Minimum Lot Area
OS	Open Space	10 acres
AE	Agricultural Exclusive	40 acres
RA	Rural Agriculture	1 acre
RE	Rural Exclusive	10,000 sq. ft

Land use designations found in the Ventura County General Plan serve as guidelines for countywide zoning. Four land use designations were included in the WOA model: Agriculture, Agriculture-Urban Reserve, Open Space, and Open Space-Urban Reserve (See Figure 6.3). Urban Reserve land use designations serve as indicators of possible future urban development, and as such, were ranked higher in the model. General Plan land use designations can influence how easily a parcel can be developed. Depending on the land use designation, some parcels can be rezoned more easily than others. As with zoning, parcels with land use designations that have more allowable uses that facilitate development have higher scores than parcels that are have fewer and may be more difficult to rezone.

Countywide zoning was paired with General Plan land use designation in the ROI to identify areas with the highest development pressure. The combination of zoning and land use designation were ranked according to those that could most easily be rezoned for future development (See Table 6.2).

Table 6.2: Ranking of combined zoning and General Plan land use designation

Rank	Zoning	Land Use
1	AE	Open Space Urban Reserve
2	AE	Agriculture Urban Reserve
3	RA	Agriculture
4	RE 1 acre	Open Space
5	RE 1 acre	Agriculture
6	RE 5 acre	Agriculture
7	RE 20 acre	Open Space
8	OS 10 acre	Open Space
9	OS 20 acre	Open Space
10	OS 80 acre	Open Space
11	OS 160 acre	Open Space
12	AE	Open Space
13	OS 20 acre	Agriculture
14	OS 80 acre	Agriculture
15	OS 160 acre	Agriculture
16	AE	Agriculture

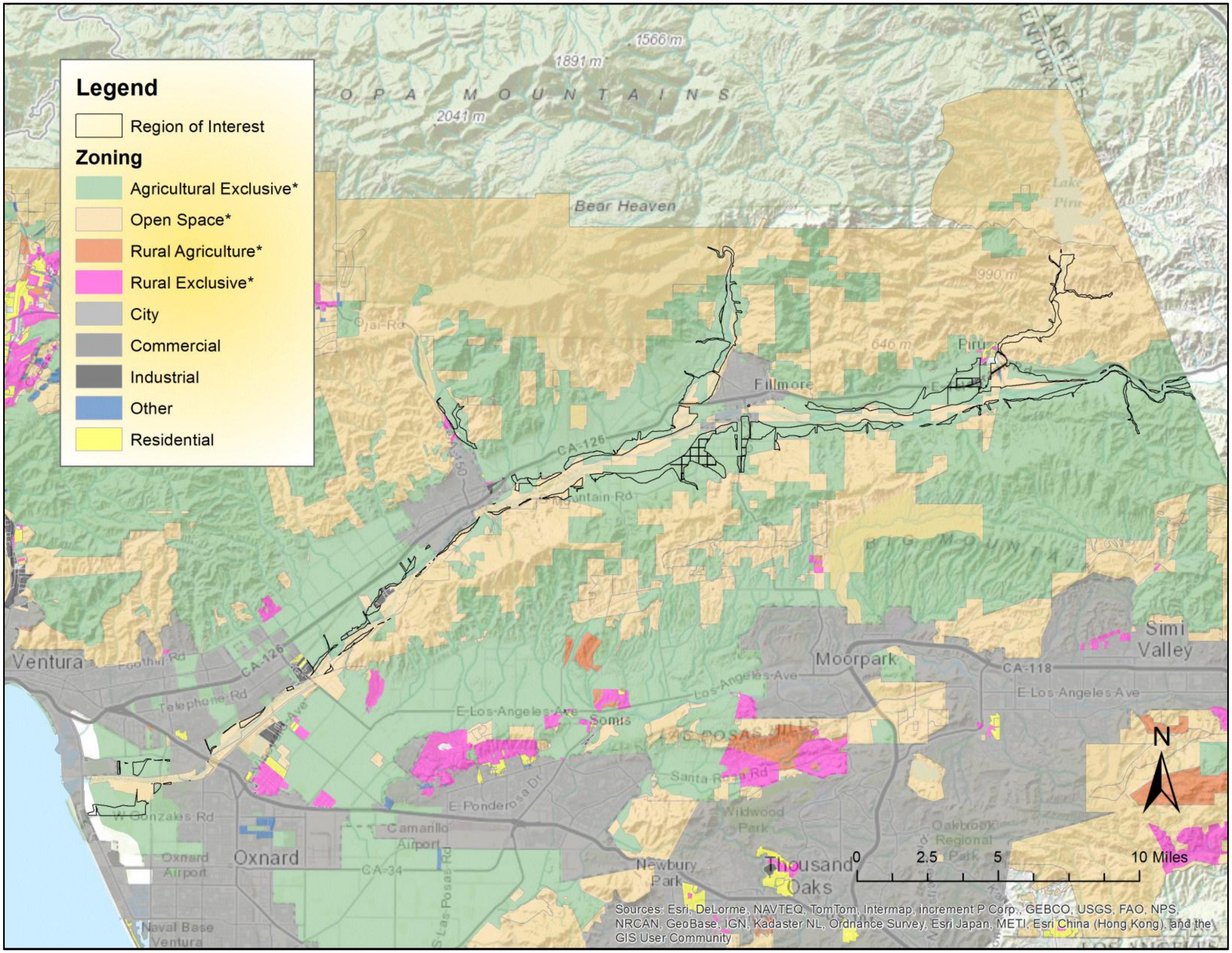

Figure 6.2: Countywide Zoning (*represents Zoning considered in this analysis)

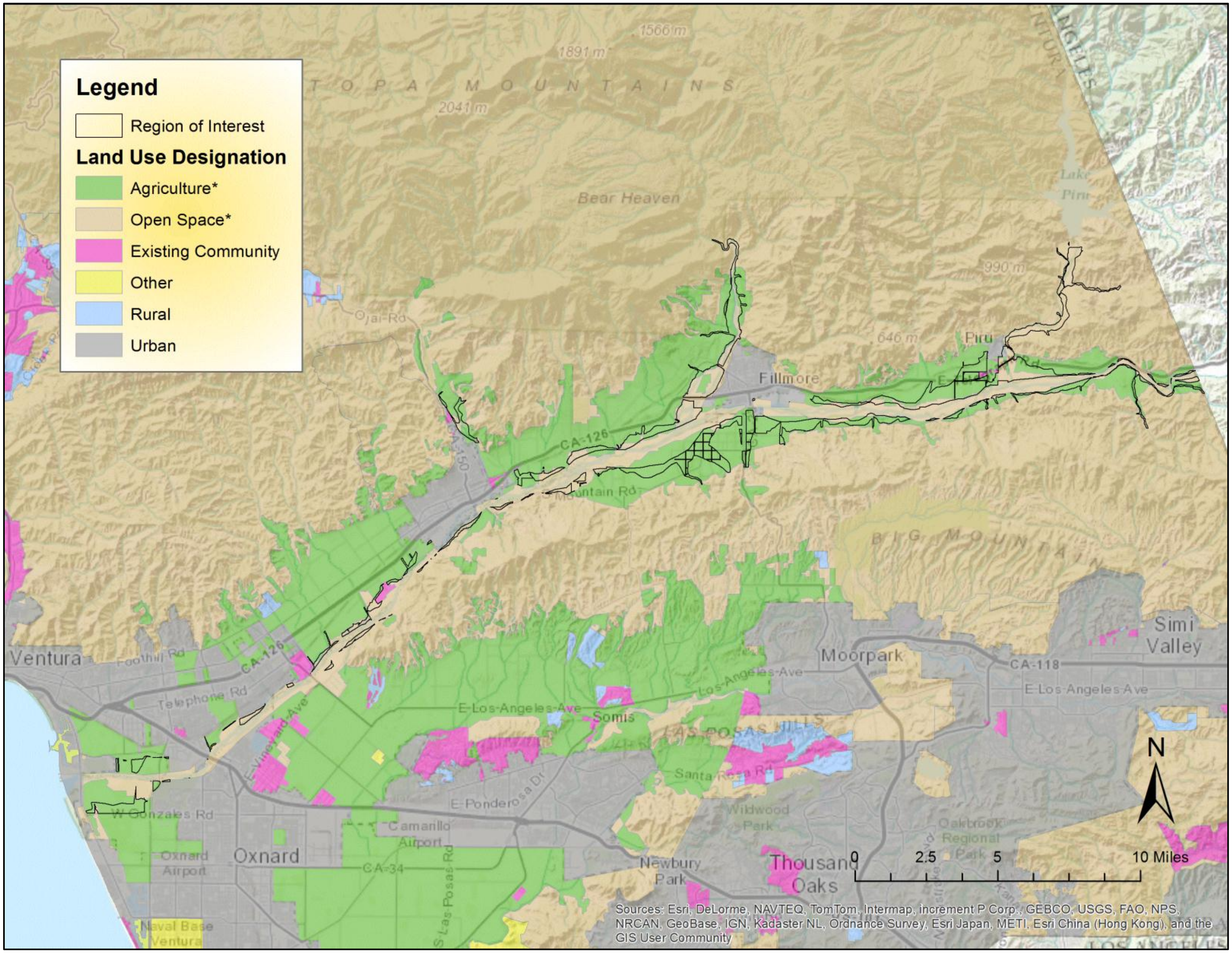

Figure 6.3: General Plan Land Use Designations (*represents land use designations considered in this analysis)

Urban Growth Boundaries

Urban growth boundaries surround urban development and are meant to control sprawl. Areas closer to urban growth boundaries are more likely to become developed in the future, in part, because of the ease of extending existing utility services. The Ventura County SOAR policy restricts changes to the county's general plan without voter approval while individual city SOAR policies restrict annexation outside CURB boundaries without voter approval. County SOAR and city CURB delineations do not always coincide. Additionally, Ventura has a sphere of influence larger than CURB and County SOAR delineations. In this project, the largest urban growth boundary surrounding an urban area was used (See Figure 6.4). Table 6.3 shows each urban area and the urban growth boundary used for the WOA model. Urban growth boundary scores in the WOA were based on distance to urban growth boundaries. Because parcels closer to urban growth boundaries are generally more likely to become developed in the future, these parcels were given higher development pressure scores.

Table 6.3: Designated Boundary used to determine Region of Interest for the WOA

Urban Area	Urban Growth Boundary Used
Ventura	City Sphere of Influence
Saticoy	County SOAR
Santa Paula	CURB
Fillmore	CURB
Piru	County SOAR

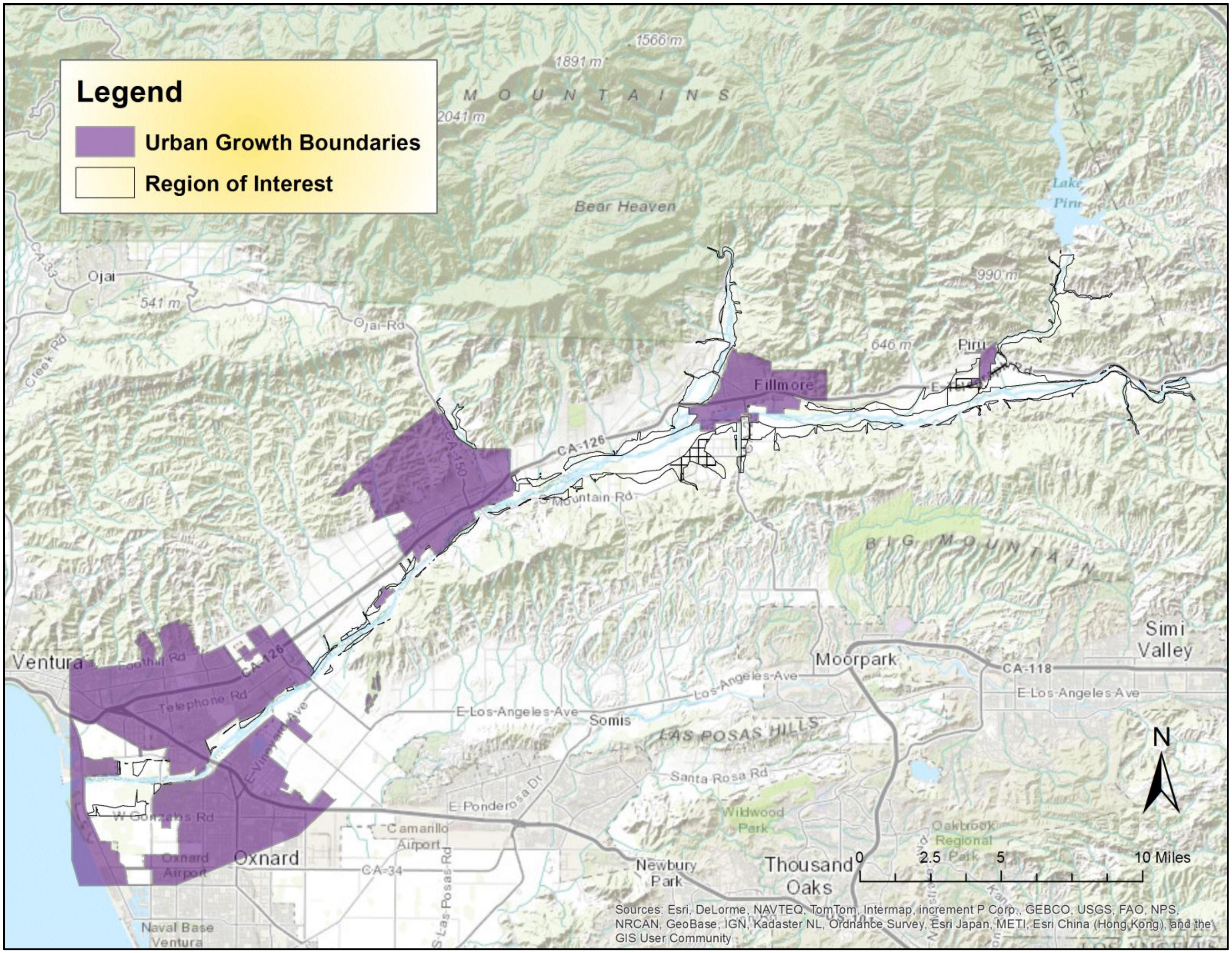

Figure 6.4: Urban Growth Boundaries along Region of Interest

Transportation Networks

Major roads and local roads were used as indicators of development pressure for the WOA model. Spatial data on roads was obtained from the United States Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) database (See Figure 6.5). The primary major road in the ROI was Highway 126, which runs parallel to the Santa Clara River. Most urban areas in the ROI are well connected with a local road network.

Predicting development based on proximity to major and local roads is a complex relationship that can be very specific to geographic areas. A report published in 2003 by the Solimar Group found that in Ventura County major roads repelled development while local roads attracted it (Fulton et al., 2003). Despite this finding, county planners generally recognize a positive correlation between proximity to major and local roads and development. Because of this correlation, and the narrow ROI for this project, major and local roads were modeled to have a positive relationship to development in the WOA, giving parcels closer to major and local roads higher development pressure scores than those farther away.

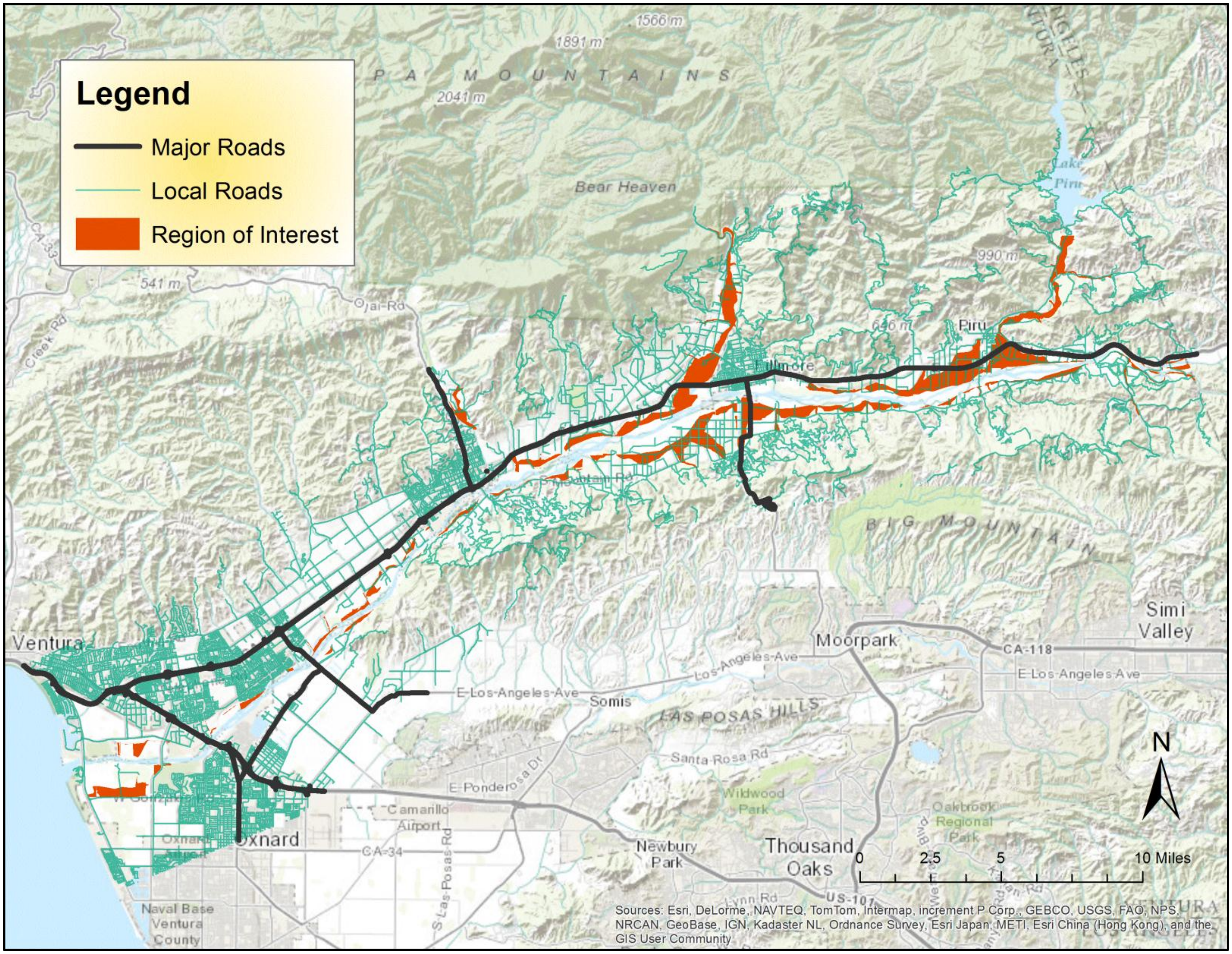

Figure 6.5: Major and Local Roads in Ventura County

Floodway and Floodplain

FEMA designates floodways and floodplains for most major rivers in the United States. Development is more likely to occur in the 500-year floodplain than the 100-year floodplain because of fewer regulations and decreased risk of flooding damage. Because development in the 100-year floodplain is more prone to flooding damage, Floodplain Development Permits as well as insurance are required prior to construction. FEMA floodplains and floodway delineations were obtained from the VCWPD. Parcels zoned in the 500-year floodplain were given higher development pressure scores because they are easier to develop than parcels in the 100-year floodplain.

Levee Tie-In Capability

Eight levees within the ROI were identified and used for this analysis (See Table 6.4 & Figure 6.6). These include structures constructed by the United States Army Corps of Engineers, Ventura County Watershed Protection District, cities, and private landowners. Earthen levees or similar levee like structures were not included in the analysis because of their temporary nature and lack of protection during extreme flood events. Levees used in the model were identified by the VCWPD as structural flood control structures in the floodplain. Parcels closer to existing levee endpoints make development more likely because of the lower cost associated with tying into an existing levee, thus parcels closer to levee ends were given a higher development pressure scores in the WOA model.

Table 6.4: Levees in ROI

Levee Name	Construction
Santa Clara River 1 (SCR-1)	VCWPD
Santa Clara River 2 (SCR-2)	VCWPD
Santa Clara River 3 (SCR-3)	USACE
Santa Paula Creek 1 (SPC-1)	USACE
Santa Clara River 4 (SCR-4)	Private Landowner
Sespe Creek 1 (SC-1)	USACE
GCW-1	VCWPD
Santa Clara River 5 (SCR-5)	Private Landowner

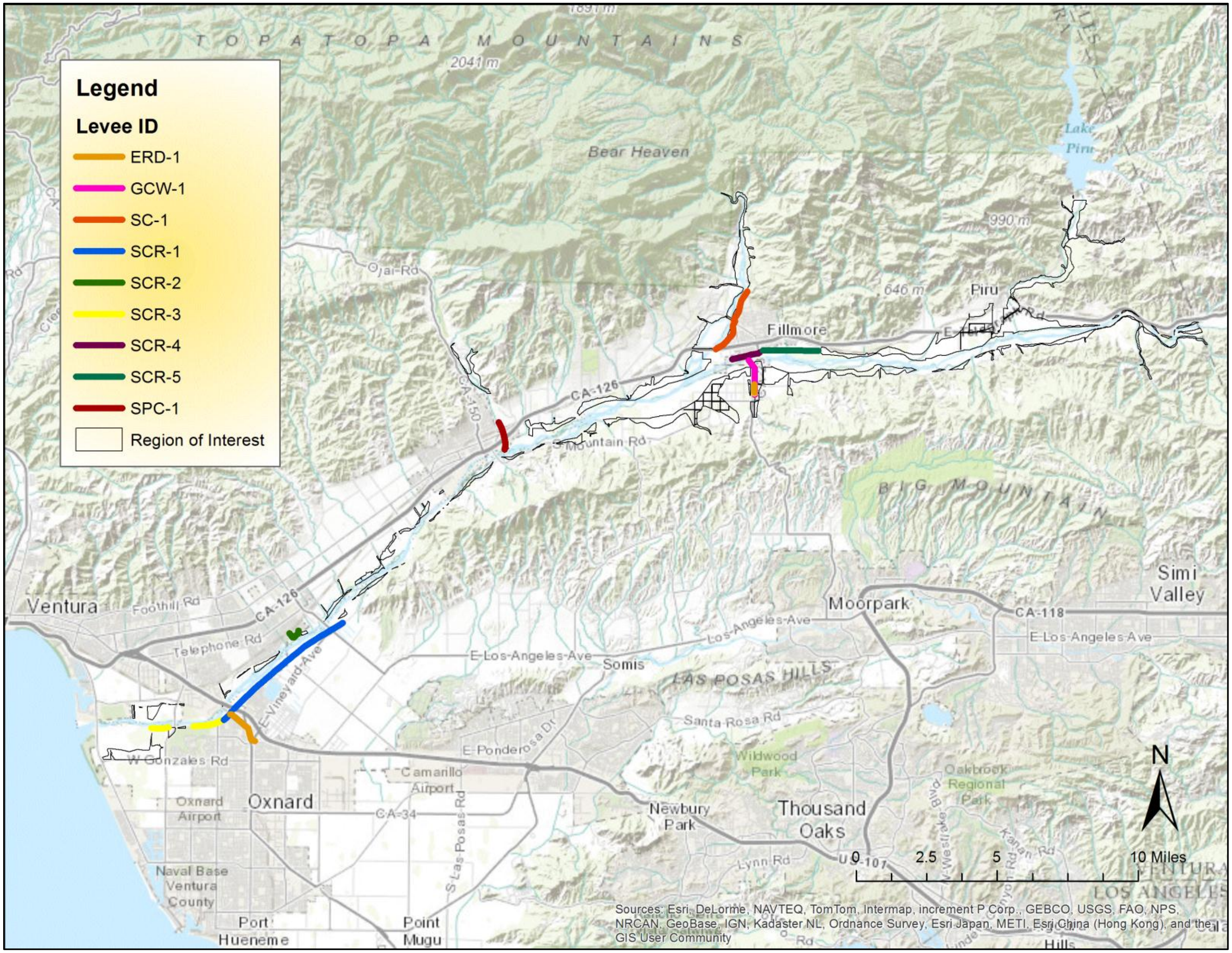

Figure 6.6: Levees along Region of Interest used in the WOA

Parcel Size

Parcel data was obtained from the Ventura County Assessor's roll. Parcel size was included as an input factor in the WOA model because of transaction costs associated with parcel acquisition. Because it is more cost effective for developers to buy one large parcel than several small parcels, larger parcels were given higher development pressure scores than smaller parcels in the WOA model.

Weighted Overlay Analysis Model

The WOA model was created in ESRI's ArcMap 10.1 using ModelBuilder. The seven input factors used in the model were converted from vector data to raster data for spatial analysis. County zoning/General Plan land use designations and floodplain designations were converted to raster data using the polygon to raster tool. Major roads, local roads, levee end points, and urban growth boundaries were converted to raster data using the euclidean distance tool. All raster data had a cell size of 5 feet by 5 feet.

Rasterized input factors were reclassified using the reclassify tool. Input factor scores ranging from one to four were assigned to each input factor raster based upon distance to feature, zoning designation, and floodplain designation. Table 6.5 shows the reclassification scheme used in the WOA model. Input factor scores of four represented cells with high development pressure while scores of one represented cells with the lowest development pressure.

Table 6.5: Priority Scoring for WOA Input Factors

Threat of Development Input Factor Scoring				
Factor	**4**	**3**	**2**	**1**
County Zoning/ General Plan Land Use Designation	AE / OS UR	AE, RA, RE / Ag UR, Ag, OS	RE, OS / OS	AE, OS / OS, Ag
Distance from Urban Growth Boundary	0-1/3 mile	1/3-2/3 mile	2/3-1 mile	>1 mile
Parcel Size (acres)	139-373	48-138	13-48	0-13
Floodplain Designation	500-year floodplain	100-year floodplain	-	-
Major Roads	0-1/3 mile	1/3-2/3 mile	2/3-1 mile	>1 mile
Local Roads	0-1/18 mile	1/18-1/9 mile	1/9-1/6 mile	>1/6 mile
Levee Tie-In Capability	0-1/6 mile	1/6-1/3 mile	1/3-1/2 mile	>1/2 mile

An example of how each of these input factors was scored using ModelBuilder tools can be seen in Figures 6.7-6.11. The example used shows how the levee tie-in input factor score was calculated. The levee end point shape file was first converted to raster data by using the euclidean distance tool (See Figure 6.8). This tool converts vector data into raster data and created a buffer around the identified feature, in this case levee end points. These distances were then reclassified (See Figure 6.9) to give cells an input factor score. Parcels were next given an input factor score using the zonal statistic tool (See Figure 6.10). This type of methodology was done for all input factors in the WOA model.

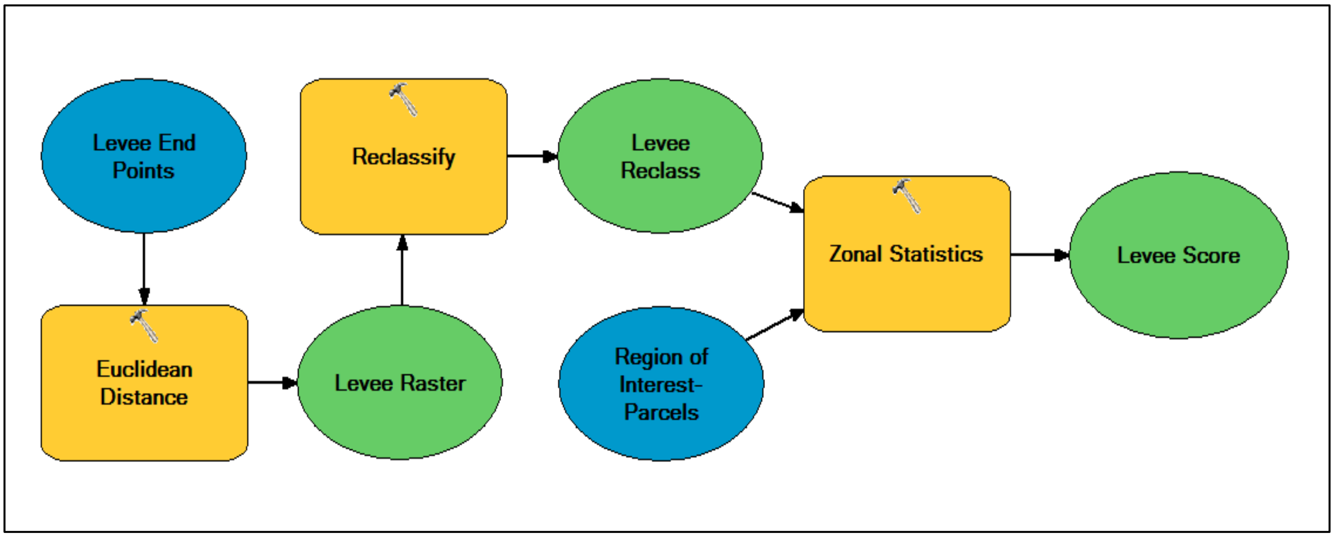

Figure 6.7: Tool pathway for levee tie-in input factor used in WOA mode. Levee Score was combined with other input factor zonal statistics to calculate the weighted sum zonal statistic.

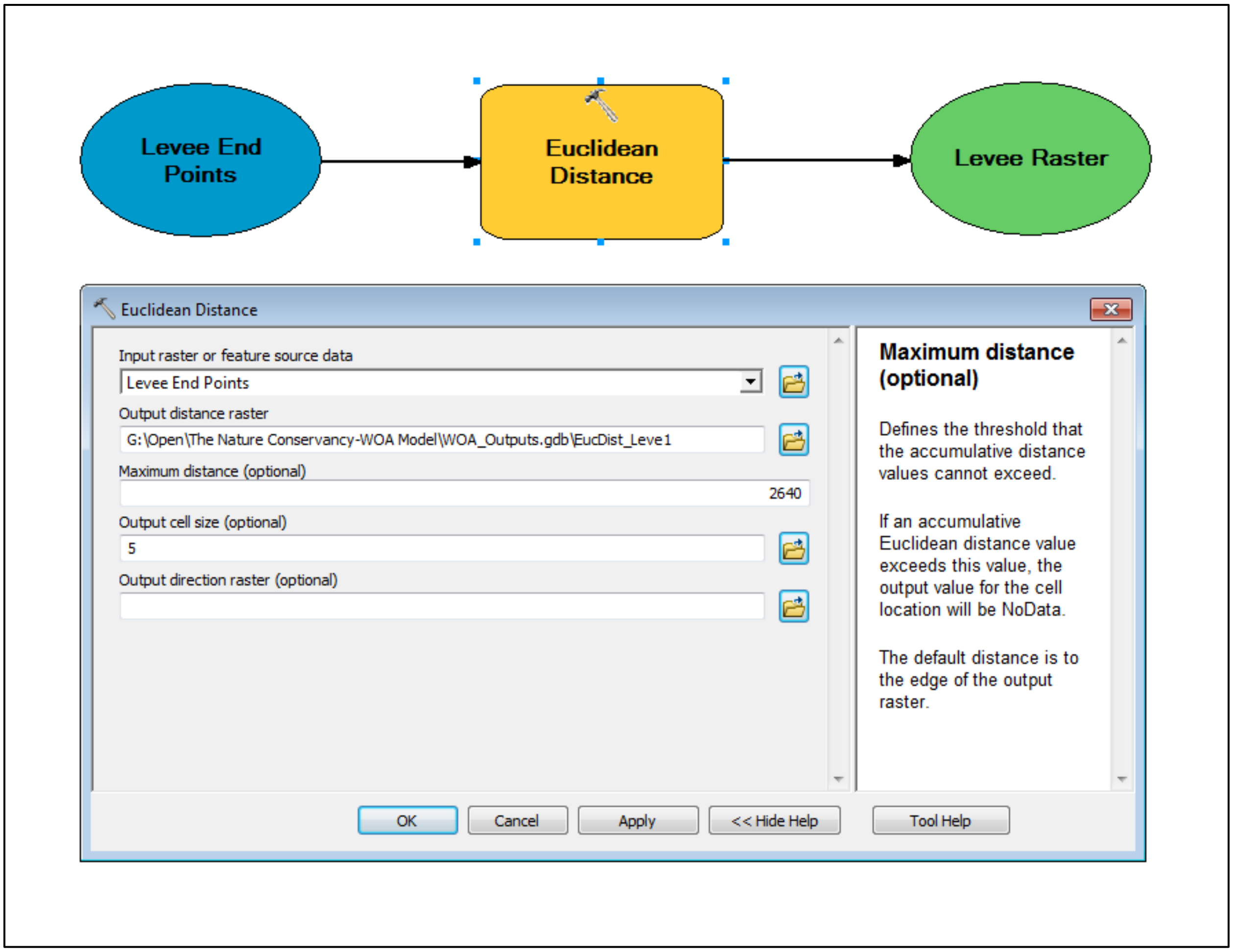

Figure 6.8: Euclidean distance tool used to create raster data for levee tie-in input factor. Half mile maximum distance was used to reclassify data for WOA model.

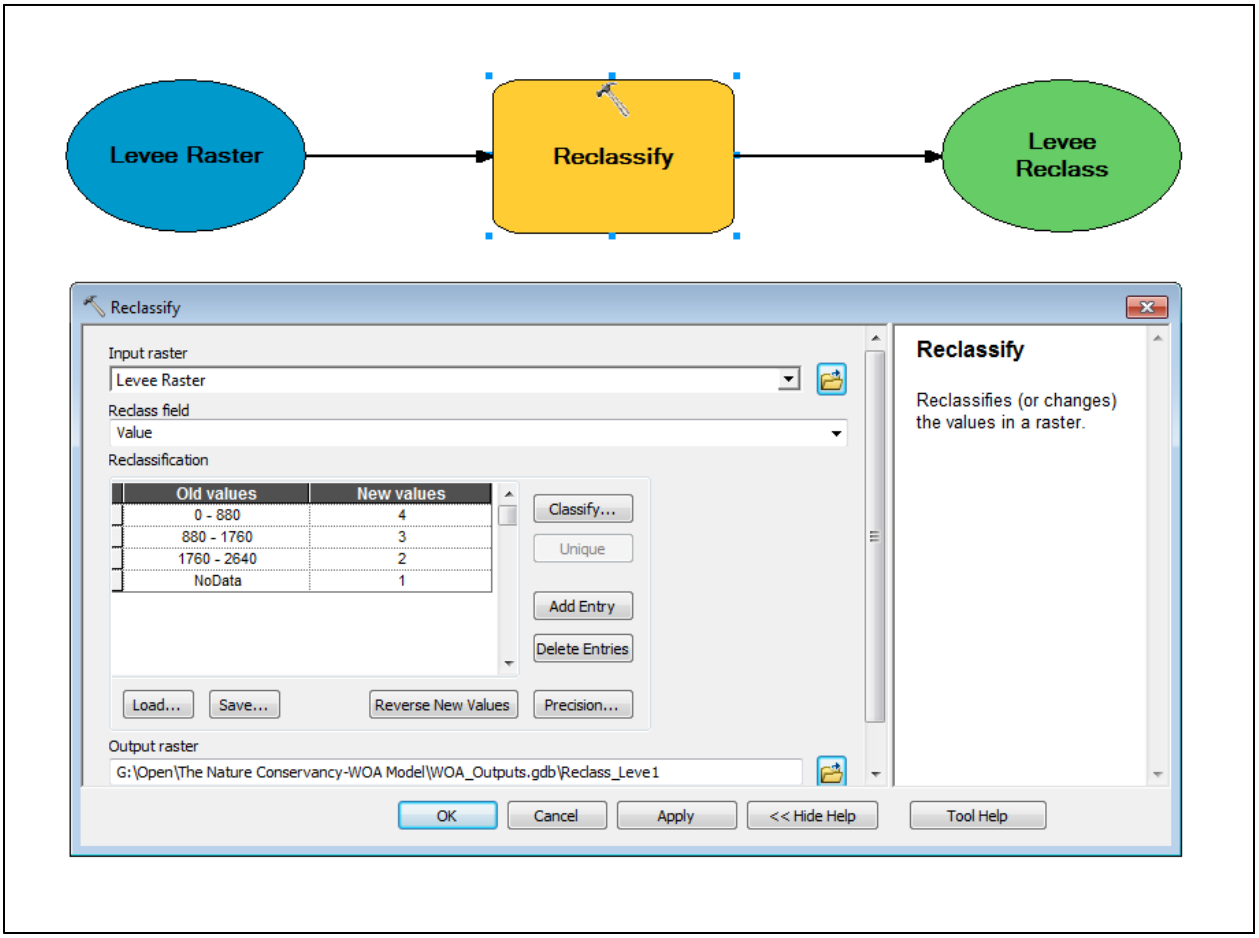

Figure 6.9: Reclassification of Distance to Levee End Points. The old values indicate the distance in feet from a levee endpoint. These value ranges are then reclassified into four new values, representing our WOA scores for this factor.

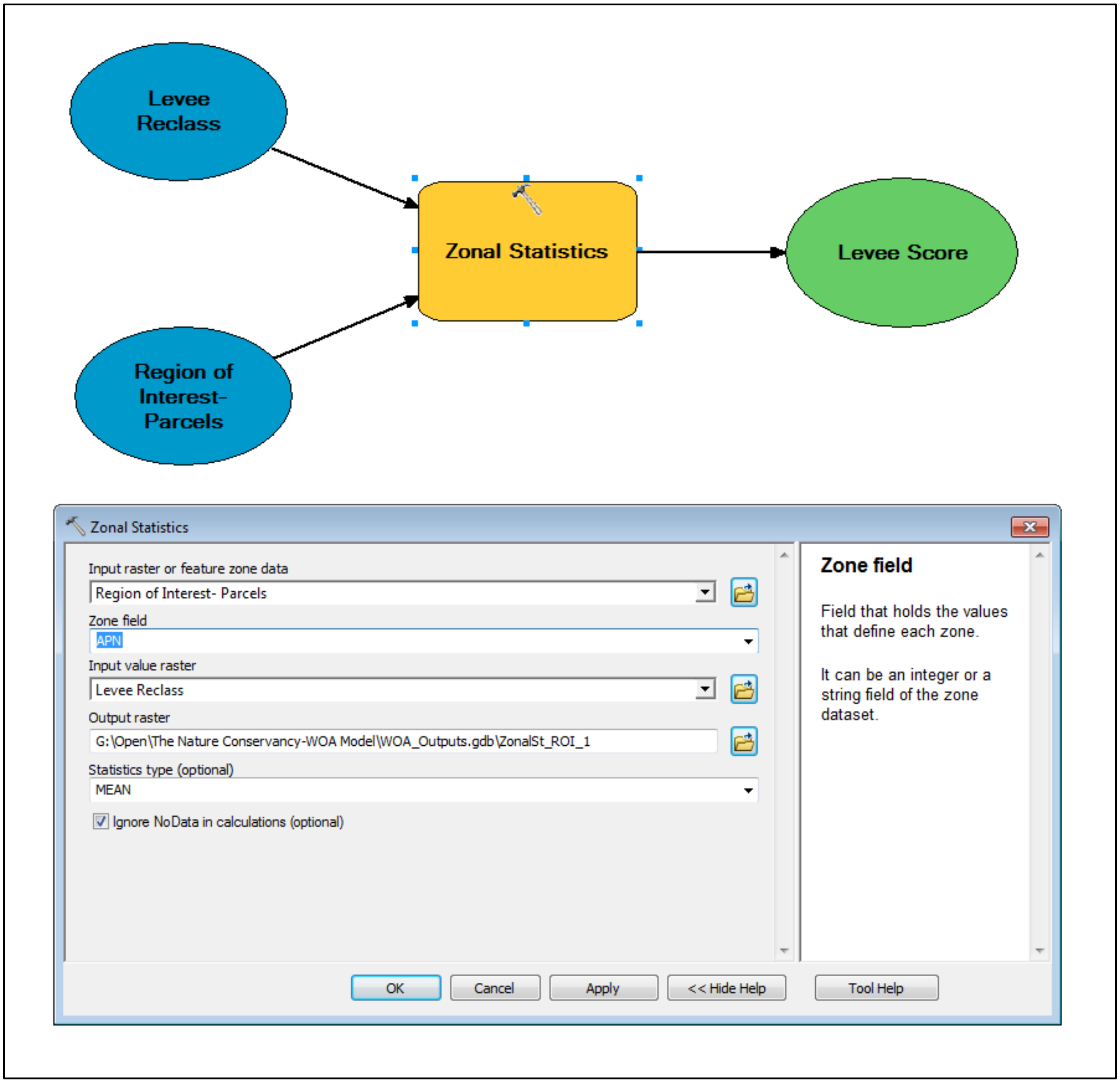

Figure 6.10: Zonal Statistic tool used to classify individual parcels based upon the Levee Reclassification. Levee Score represents the WOA levee score given to individual parcels.

Following the same methodology, parcels were given input factor scores for each of the seven factors in the model. The seven input factors were combined to create one zonal score for each parcel by using the weighted sum tool. This tool allows for multiple inputs to be weighted accordingly producing a single output (See Figure 6.11). Weights used in the weighted sum tool will be discussed later in the document. The weighted sum output produces a final score for each individual parcel which is called the final WOA score. Final WOA scores were ranked highest to lowest indicating varying degrees of development pressure. Higher scores represent parcels with the highest development pressure while lower scores represent parcels with lower development pressure.

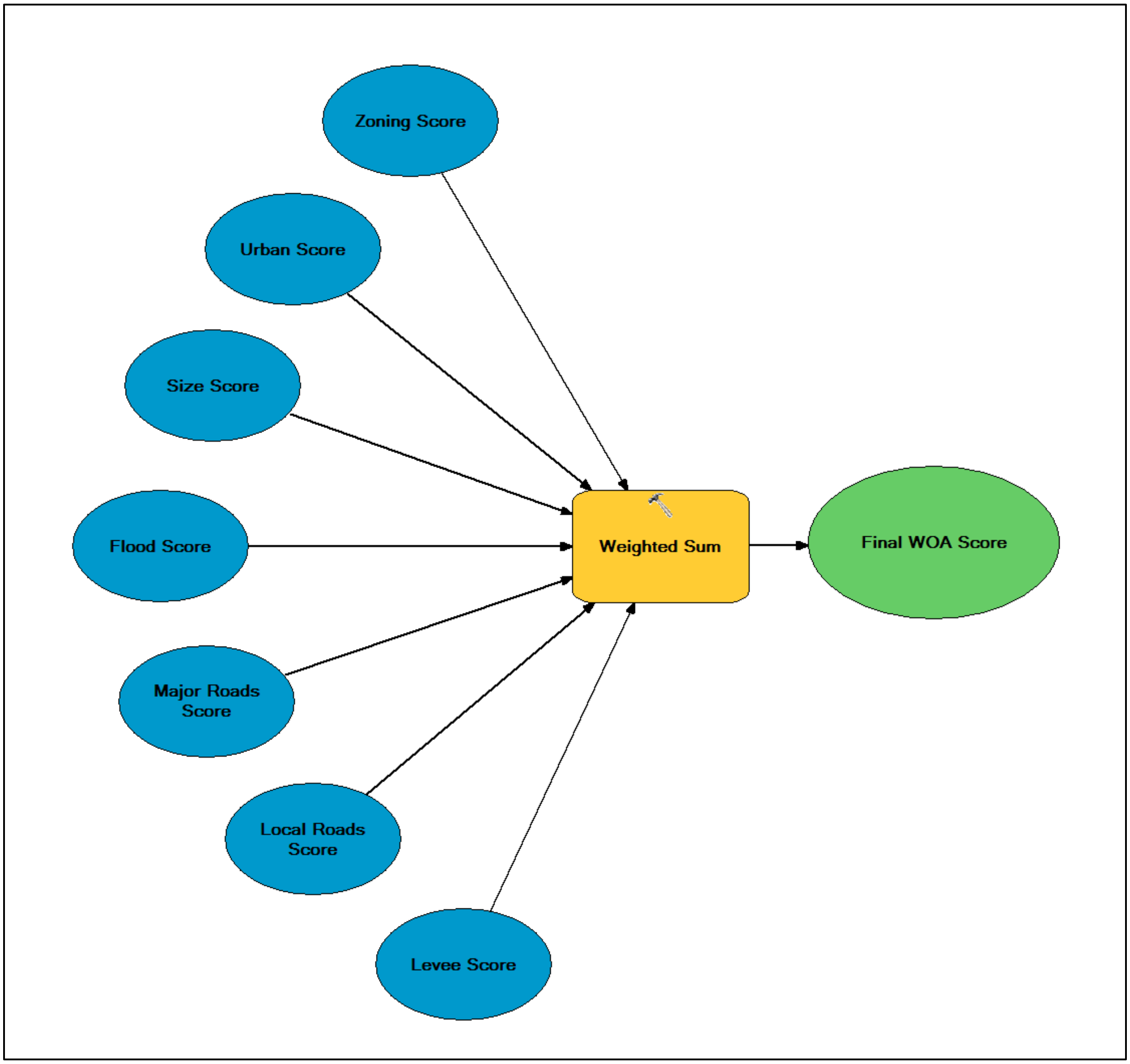

Figure 6.11: Weighted Sum Tool-The weighted sum tool was used to combine the seven input factor score in the WOA model. The Final WOA Score represents the combined score given to each parcel.

Table 6.6: Weights assigned to each WOA input factor. These weights were derived from input from county planners and Saaty's Analytical Hierarchy Process

Factors	Weights
County Zoning & General Plan Land Use	0.334
Urban Growth Boundary	0.279
Parcel Size	0.172
500 vs. 100 Year Flood Plain (YFP)	0.099
Major Roads	0.055
Minor Roads	0.040
Levee tie-in	0.020

Development of Input Factor Weights - The Analytical Hierarchy Process

The WOA weights used in the weighted sum tool were assigned using the Analytical Hierarchy Process (AHP), a structured decision-making tool that was developed by Thomas L. Saaty in the 1970's. AHP consists of pairwise comparisons of each contributing factor relative to one another resulting in a ratio of importance. The greater the relative importance of one factor over another, the greater the ratio. As an example, comparing zoning and parcel size leads to a ratio of 5:1 because zoning has stronger importance than parcel size when predicting future development. Table 6.7 provides ratios of importance as well as a description and explanation of the resulting comparison.

Table 6.7: Analytical Hierarchy Process Comparison Ratios and Descriptions

Ratio[1]	Description	Explanation
1:1	Equal Importance	Zoning and parcel size are of equal importance
3:1	Moderately more important than the other	Zoning is moderately more important than parcel size
5:1	Strong importance over the other	Zoning takes strong importance over parcel size
7:1	Very Strong importance over the other	Zoning takes very strong importance over parcel size
9:1	Absolute importance over the other	Zoning is absolutely more important than parcel size
[1] Ratios can also utilize even numbers for intermediate values		

Adapted from (Harper and Vargas, 1987)

A pairwise comparison was conducted for each of the seven factors in the WOA. Table 6.8 shows the resulting output from these comparisons. The peach cells represent one set of ratios, while the green cells represent the reciprocal ratio. For instance, a comparison of zoning and parcel size yields a 4:1 ratio, while the corresponding comparison in a green cell yields a 1:4 ratio or 0.25 value.

Table 6.8: Pairwise Comparison Ratio Output Table.

	Zoning & Land Use	Urban Growth Boundary	Parcel Size	500 v 100 YFP	Major Roads	Minor Roads	Levee tie-in
Zoning & Land Use	1	2	3	5	6	7	9
Urban Growth Boundary	0.50	1.00	3.00	5.00	7	8	9
Parcel Size	0.33	0.33	1.00	3.00	5	7	9
500 v 100 YFP	0.20	0.20	0.33	1.00	3	5	7
Major Roads	0.17	0.14	0.20	0.33	1	3	4
Minor Roads	0.14	0.13	0.14	0.20	0.33	1.00	5.00
Levee tie-in	0.11	0.11	0.11	0.14	0.25	0.20	1.00
Totals	2.45	3.91	7.79	14.68	22.58	31.20	44.00

Table 6.9 represents the normalized ratios from the table above. Normalization is achieved by taking each value in Table 6.8 and dividing it by the total value at the bottom of its respective column. For example, the first cell in the upper left corner of Table 6.8 (1) is divided by the total (2.66) to yield 0.38 in the same cell in Table 6.9. This normalization ensures that all ratios in a column sum to one. Next, the average value of a column (input factor) is computed by summing the values in each row and dividing it by the number of factors (7). These average values for each row are the eigenvectors of the matrix and the weights we used in our WOA.

Table 6.9: Normalized Ratios of Pairwise Comparisons

	Zoning & Land Use	Urban Growth Boundary	Parcel Size	500 v 100 YFP	Major Roads	Minor Roads	Levee tie-in	totals	**Weights**
Zoning & Land Use	0.41	0.51	0.39	0.34	0.27	0.22	0.20	2.34	**0.334**
Urban Growth Boundary	0.20	0.26	0.39	0.34	0.31	0.26	0.20	1.96	**0.279**
Parcel Size	0.14	0.09	0.13	0.20	0.22	0.22	0.20	1.20	**0.172**
500 v 100 YFP	0.08	0.05	0.04	0.07	0.13	0.16	0.16	0.70	**0.099**
Major Roads	0.07	0.04	0.03	0.02	0.04	0.10	0.09	0.38	**0.055**
Minor Roads	0.06	0.03	0.02	0.01	0.01	0.03	0.11	0.28	**0.040**
Levee tie-in	0.05	0.03	0.01	0.01	0.01	0.01	0.02	0.14	**0.020**

A consistency analysis was conducted to ensure that the ratios of importance are consistent, i.e. there are no comparisons that logically conflict. An example of inconsistency would be if choice A is weighted higher than choice B which is weighted higher than choice C, but Choice C is somehow weighted higher than Choice A. This is achieved by calculating the consistency measures, consistency index, and consistency ratio (See Table 6.10). Consistency measures are calculated by using matrix multiplication to find the product of a row of values in Table X.3 and multiplying it by the row of seven weight values in Table X.4 then dividing the product by the weight for that row (See Figure 6.12). The consistency index is then found through the following formula:

$$Consistency\ Index\ (CI) = \frac{A - n}{n - 1}$$

In this formula, *A* is the average of the 7 values in a row in Table X.4 (leaving out the “total” and “weights”) and *n* represents the number of factors considered (7 in this case).

The Random Index (RI) represents the mean consistency index of a matrix of a particular size *n*, these values were computed by Saaty’s research in 1980 (Saaty 1980). Because our matrix has 7x7 dimensions, the corresponding value used in the consistency ratio is 1.32 (See Table 6.10). The consistency ratio is computed by the following formula:

$$Consistency\ Ratio = \frac{CI}{RI}$$

Table 6.10: Consistency Measures and Consistency Ratio

Consistency Measure	
Zoning & Land Use	8.07
Urban Growth Boundary	8.39
Parcel Size	8.19
500 v 100 YFP	7.89
Major Roads	7.62
Minor Roads	7.04
Levee tie-in	7.26
Consistency Index	0.13
Random Index	1.32
Consistency Ratio	0.098

Table X.3	Zoning & Land Use	SOAR/ CURB	Parcel Size	500 v 100 YFP	Major Roads	Minor Roads	Levee tie-in
Zoning & Land Use	1	2	3	5	6	7	9
SOAR/CURB	0.50	1.00	3.00	5.00	7	8	9
Parcel Size	0.33	0.33	1.00	3.00	5	7	9
500 v 100 YFP	0.20	0.20	0.33	1.00	3	5	7
Major Roads	0.17	0.14	0.20	0.33	1	3	4
Minor Roads	0.14	0.13	0.14	0.20	0.33	1.00	5.00
Levee tie-in	0.11	0.11	0.11	0.14	0.25	0.20	1.00
Totals	2.45	3.91	7.79	14.68	22.58	31.20	44.00

Table X.4	Weights
Zoning & Land Use	0.334
SOAR/CURB	0.279
Parcel Size	0.172
500 v 100 YFP	0.099
Major Roads	0.055
Minor Roads	0.040
Levee tie-in	0.020

Consistency Measure for Zoning & Land use =
Matrix multiplication (Table X.3 Zoning & Land Use Row * Table X.4 "Weights" column) / Zoning & Land Use Weight

This calculation is completed for each factor

Figure 6.12: Calculation of the Consistency Measure. This figure describes how the consistency measure for zoning was calculated. A similar calculation was conducted for each additional factor using the row of values in Table 6.8 and multiplying it by the same column of weight values in Table 6.9 and dividing the matrix product by the respective weight for that factor.

The consistency ratio should be less than or equal to 0.1, if this is not the case, pairwise comparisons should be revised to be more consistent. The consistency ratio computed for the WOA weights was 0.098 (See Table 6.10).

6.2 SLEUTH

Model Summary

The SLEUTH Model produces spatial data predicting the likelihood of future development and land use change in a regional area using images that capture land use and urban development conditions from previous time periods. It was developed by Professor Keith Clarke of UCSB's Geography Department and has been used successfully for small and large datasets predicting development for San Francisco, Chicago, Washington-Baltimore, Sioux Falls, previously in Ventura County, and international metropolitan areas.

SLEUTH is a tightly coupled, modified cellular automaton model of urban and land cover change. It consists of an Urban Growth Model (UGM) that drives a second component, the Land Cover Deltatron (LCD) model. The SLEUTH model can operate without the LCD providing urban development predictions without land use data. SLEUTH uses the following input data elements that comprise its name: Slope, Land Use, Elevation, Urban, Transportation, and Hillshade. Each of these factors enables and constrains development and are used in conjunction to predict the likelihood of development on a cell- or pixel-based scale out to a particular year in the future. Data for each of these factors consists of 8 bit grayscale gif files that contain the development constraints given to each cell and range from 0-100 values. These values are used as inputs for the model. For more detailed information about how the SLEUTH model works, see Appendix X.

Modes of Operation:

The program has three primary modes: Test, Calibrate, and Predict.

<u>Test Mode</u>: The test mode tests the data and model code for errors.

<u>Calibration Mode</u>: Because calibrating the model is computationally extensive, SLEUTH calibration mode utilizes the Brute Force method to derive the coefficients for each parameter. This involves starting with a “coarse” scale calibration and sequentially narrowing the range of coefficient values and increasing the data resolution through the “fine” and “final” phase calibration.

All calibration modes use gif image data for each of the six factors from previous time periods to calibrate the model’s coefficients (dispersion, breed, spread, slope, and road gravity) and predict the conditions in images from the more recent past. In other words, the model uses historical development patterns in the study area to calibrate and refine model parameters so that it is able to accurately predict known development patterns in the past. This calibration, along with the constraints inherent in each of the files, should allow the model to predict development in the future once in prediction mode. During calibration, for every year that real data exists, the urban extent is written out in grid form. An averaged value is then computed for each grid at the end of all simulations, and this data is placed in a statistical output file called avg.log. These files were used in the final step of calibration to derive the final set of coefficients used in prediction mode.

Coarse Calibration: During Coarse Calibration, the full range of coefficient values are explored (0-100) with an interval (or “step” as it described in the scenario file) of 25. Four Monte Carlo iterations were run for the coarse calibration.

Fine Calibration: The fine calibration utilizes the output from the coarse calibration to determine a narrowed range of coefficients. This is achieved by using the Optimum SLEUTH Metric (OSM), an analysis that determines the coefficients in the model that produce the best fit. The fine calibration utilizes the top ten best fitting coefficients as inputs. The lowest and highest coefficient values were selected as a range. Next, the “step” parameter was determined by dividing this range into 5 to 6 equal intervals. For example, if the minimum and maximum values were 25 and 50 respectively, than a step value of 5 would be appropriate. Our coefficient ranges used for the fine calibration are included in Table 6.11. Eight Monte Carlo iterations of the model were run for the fine calibration.

Table 6.11: Coefficients used in the fine calibration taken from the top 10 coefficients produced in the OSM analysis

	Diffusion	Breed	Spread	Slope	Road
Minimum	15	1	75	1	1
Maximum	100	100	100	5	50
Step	15	25	5	1	10

Final Calibration: For the final calibration, the OSM analysis was run again on the output file from the fine calibration. The final calibration utilizes the top three coefficients and the minimum and maximum values are used as inputs for calibration. Again, the step value was determined by creating 5-6 values equally spaced within this range for each coefficient. Ten Monte Carlo iterations of the model were run for the final calibration.

Table 6.12: Coefficients used in the final calibration taken from the top three coefficients produced in the OSM analysis

	Diffusion	Breed	Spread	Slope	Road
Minimum	25	41	95	3	1
Maximum	55	81	100	5	41
Step	5	8	1	1	8

Predict Mode:
The top ranking coefficient values are selected from this analysis and entered as the "best fit" values into the scenario file. The model guidance recommends at least 100 Monte Carlo iterations be run for the prediction mode. These best fit coefficient values are used for the first year of the model and adapt and change as the model runs for each successive year depending on the growth that occurs and the limitations imposed by the six input data layers.

Table 6.13: The best fit values are also taken from OSM analysis and represent the single best coefficients run in the final step of the model

	Diffusion	Breed	Spread	Slope	Road
Best Fit Values	30	65	99	5	41

SLEUTH Data

Historical data sets were obtained from Professor Jeff Onsted of Florida International University, who ran the model previously for Ventura County as a part of his PhD dissertation work at UCSB in 2002. Professor Onsted used historic aerial photographs of Ventura County to produce grayscale images for both 1945 and 1963 that display urban boundaries and roads in 1945 to calibrate the original model. Data from the California Department of Conservation's

Farmland Monitoring and Mapping Project (FMMP) was utilized to provide urban boundary spatial data for 1984, 2002, and 2010. Roads data was obtained from Professor Onsted who utilized the 2000 Tiger Roads data. All gif images developed for the project were formatted to the same resolution as those made by Professor Onsted, 810x582 pixels, 72 dots per inch (dpi). Table 6.14 provides a list of all data images used as inputs for the model and their data source.

Table 6.14: SLEUTH Data Input Layers and Sources

SLEUTH Layer	Data	Source
Slope	DEM representing percent slope gif	DEM, National Elevation Dataset, Jeff Onsted, USGS NED 1/3 arc second (USGS, 2013)
Land Use	Data omitted due to model errors	--
Exclusion	A 75% exclusion layer developed from the County SOAR boundary was used for calibration. Three Exclusion layers were used in the prediction mode: 1.) Zoning based Exclusion Layer 2.) 0% Exclusion layer, 3.) 75% Exclusion layer developed from the County SOAR boundary	VCPD, modified for project
Urban	Urban boundary 1945 gif	Jeff Onsted, aerial photographs
	Urban boundary 1963 gif	Jeff Onsted, aerial photographs
	Urban boundary 1984 gif	Jeff Onsted, Farmland Mapping & Monitoring Project (FMMP) data (FMMP, 1984)
	Urban boundary 2002 gif	Jeff Onsted, FMMP data (FMMP, 2002)
	Urban boundary 2010 gif	FMMP data, modified for project (FMMP, 2010)
Transportation	Roads 1945 gif	Jeff Onsted, aerial photographs
	Roads 2002 gif	Jeff Onsted, National Highway Planning 2000, Tiger Roads (Cal-Atlas, 2000)
Hillshade	Hillshade gif	DEM, National Elevation Dataset, Jeff Onsted, USGS NED 1/3 arc second (USGS, 2013)

After many attempts to reconcile and manipulate current land use data into gif images that would be compatible with the model, we ultimately decided to omit this component of the model. This did not impact model outputs because the land use component is not essential to run SLEUTH and was not needed to complete the project's objectives.

The model produces gif output images that show cells with varying likelihoods of development ranging from five to 100 percent. These inputs are available on a yearly basis and as a cumulative image show development prediction for the final year of the assigned time horizon, 2063. The cumulative gif image was converted to a tiff image and georeferenced to be used for further analysis in ArcGIS 10.1.The SLEUTH model output was spatially joined to the ROI to identify the parcels with the greatest probability of development. This analysis was then combined with the hydrological analysis to prioritize all parcels in the ROI.

Figure 6.13 gives an overview of the data, parameter coefficients, and process that govern SLEUTH in predict mode. It also shows how coefficient values in the "Generate Growth Cycles" section undergo self-modification and change throughout a simulation.

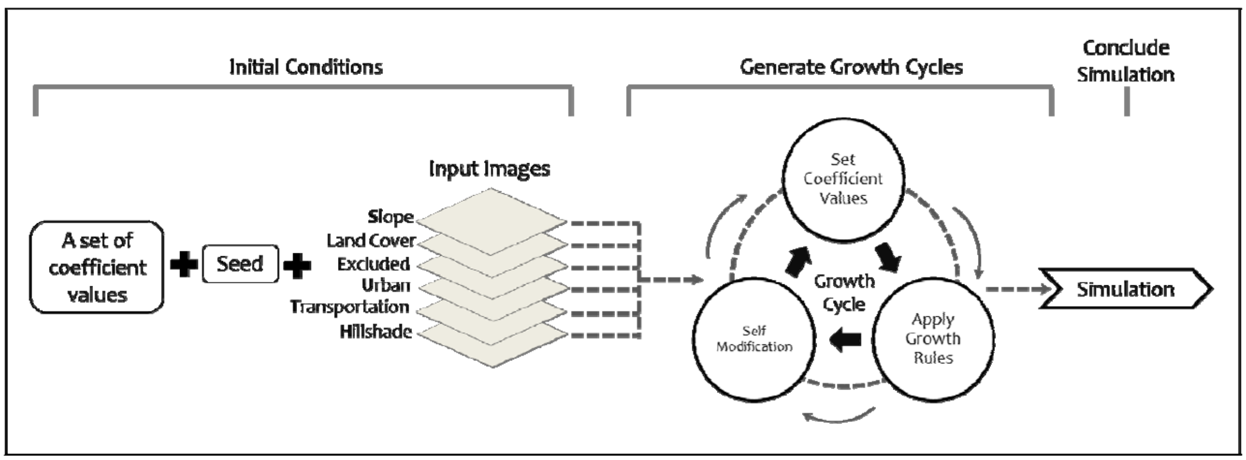

Figure 6.13: shows the model data and processes run in predict mode (Chaudhuri & Clarke, 2013)

Exclusion Scenarios

The Exclusion layer in the SLEUTH model has been modified by various researchers to predict urban development under different future scenarios. For this study, the SLEUTH model was run under three possible future growth policy scenarios in the prediction mode, with each scenario represented by a different exclusion layer. The first scenario used an exclusion layer that contains values that approximate the development restrictions of each zoning designation within the County. The results from this scenario were used in the final ranking of parcels. The second and third scenarios provide a reference for the extreme range of development policy scenarios. The zero percent exclusion shows a development scenario with no land use or regulatory restrictions, and the 75 percent SOAR boundary scenario provides a conservative development prediction in which future development is limited to areas within the current SOAR boundaries 75 percent of the time.

In recent years, zoning information has been used to promote and restrain growth within the model that reflect recent land use policy conditions. It has been argued that urban growth is anything but homogeneous, and zoning creates the opportunity for meaningful heterogeneity (White and Engelen, 1993). For this reason, Ventura County Zoning designations were used as the basis for an exclusion layer within one of the SLEUTH model scenarios. This scenario represents growth predictions that are most likely to occur if current zoning designations continue into the future. Exclusion layer values were developed based on the minimum lot size, the number and nature of allowable uses, and the purpose of the zoning designation as specified in the Ventura County Coastal Zoning Ordinance and the Non-Coastal Zoning Ordinances. Because this most accurately predicts the growth policies of the future, the results of this scenario were used in our final analysis of development pressure.

Table 6.15 provides the zoning designations used to develop values within the Exclusion layer as well as the minimum lots size and purpose of the designation. The allowable uses were reviewed, but are too numerous to include in the report and can be found in the Ventura County Zoning Ordinances. Designations in which most of the land cover would be for urban use were designated as “urban” in Table 6.15. and were given an exclusion value of zero. Thus, even if some parcels are currently undeveloped, the model scenario assumed that there are no regulatory barriers to development. A higher exclusion value was given to zoning designations that explicitly stated within either of the County Zoning Ordinances that the purpose of the designation was to restrict urban sprawl and maintain current undeveloped areas. The absolute exclusion layer value is less important as the relative differences among the various zoning designations (Onsted and Roy Chowdhury, under review).

Table 6.15: Zoning designations, whether the designation is primarily for urban or non-urban uses, purpose of the designation, and the Exclusion layer value

Zoning Code	Zoning Name	Urban/ Non-Urban	Minimum Lot Size	Purpose of Zoning Designation	Exclusion Layer Value
A-E	Agricultural Exclusive	N	10, 40, 80, 160	preserve and protect commercial agricultural lands as a limited and irreplaceable resource, to preserve and maintain agriculture as a major industry in Ventura County.	75
C-A	Coastal Agriculture	N	dependent on slope	preserve and maintain agriculture as a major industry in the coastal zone of Ventura County, and to protect these areas from the encroachment of nonresidential uses.	70
C-R	Coastal Rural	N	Not Uniformly Specified	provide for and maintain a rural residential setting where a variety of agricultural uses are also permitted, while surrounding land uses are protected.	65
T-P	Timberland Preserve	N	160	maintain the optimum supply of timberland so as to ensure continued availability and to discourage the expansion of urban services into timberland.	55
O-S	Open Space	N	10, 20, 40, 80, 160	preservation of natural resources, outdoor recreation, and the promotion of efficient municipal communities by defining the boundaries and by helping to prevent urban sprawl.	50
R-A	Rural Agriculture	N	1	provide for and maintain a rural setting where a wide range of agricultural uses are permitted while surrounding residential land uses are protected.	40
R-E	Rural Exclusive	N	10,000 sq ft	provide for and maintain rural residential areas in conjunction with horticultural activities, and	40

				to provide for a limited range of services.	
S-P	Specific Plan		permit specific	provide for the unified planning and diversified urban communities.	20
C-1	Neighborhood Commercial	U	NR	provide areas for retail convenience shopping and personal services	0
C-C	Coastal Commercial	U	Not Uniformly Specified	provide for the development of retail and service commercial uses that are intended to be neighborhood-serving or visitor-serving.	0
C-M	Coastal Industrial	U	Not Uniformly Specified	recognize existing industrial uses, and to permit other uses compatible with the Coastal Plan	0
C-O	Commerical Office	U	NR	provide suitable locations for offices and services of a professional, clerical or administrative nature.	0
C-P	Commercial Planned Development	U	Not Uniformly Specified	provide areas for a wide range of commercial retail and business uses.	0
CIT	City	U	Not Uniformly Specified	Incorporated city	0
H-P	Harbor Planned Development	U	Not Uniformly Specified	provide for uses consistent with harbor- and tourist-oriented developments.	0
M-1	Industrial Park	U	10,000sq ft	provide suitable areas for the exclusive development of light industrial, service, technical research and related business office uses in an industrial park context	0
M-2	Limited Industrial	U	10,000sq ft	provide suitable areas for the industrial and quasi-industrial activities of a light manufacturing, processing or fabrication nature.	0

M-3	General Industrial	U	10,000sq ft	provide suitable areas for the development of a broad range of general manufacturing, processing and fabrication activities.	0
R-1	Single Residence	U	6,000 sq ft	provide for and maintain areas which are appropriate for single-family dwellings on individual lots.	0
R-2	Two-Family Residential	U	7,000 sq ft	provide for and maintain residential areas allowing two single-family dwelling units or a two-family dwelling unit on lots which meet the minimum area requirements of this zone.	0
R-3	Multi Family Residential	U	.80 acres	appropriate for multi-family residential projects at densities considered by state law to be affordable by design to lower-income households.	0
R-B	Residential Beach Harbor	U	Not Uniformly Specified	provide for development and preservation of unique beach-oriented residential communities with small lot subdivision patterns.	0
R-O	Single Family Estate	U	20,000 sq ft	provide areas exclusively for single-family residential estates where a rural atmosphere is maintained by the allowing of a range of horticultural activities as well as animals for recreational purposes.	0
R-P	Residential Planned Development	U	permit specific	provide areas for communities which will be developed utilizing modern land planning and unified design techniques; this zone provides a flexible regulatory procedure	0

Our second development policy scenario utilizes an Exclusion layer in which all undeveloped areas are given an exclusion value of zero, effectively removing any additional barriers within the model for development of those cells. This scenario is commonly used by researchers and is useful in determining the importance of land use and regulatory policies since it simulates a situation in which there are no policies that constrain development (Onsted and Roy Chowdhury, under review). We constructed a zero percent Exclusion Layer in which all areas outside of the Los Padres National Forest were given an exclusion value of zero.

The zero percent exclusion layer demonstrates one development extreme, and a third Exclusion Layer provides a more conservative development scenario. The 75 percent Exclusion layer scenario was chosen as a more extreme restrictive development scenario; this shows what is likely to occur if the existing SOAR ordinance remains intact for the next 50 years, which could largely prevent development from occurring outside of existing cities and rural communities.

6.3 Hydrology Analysis- Downstream Flood Reduction Benefits

During high flood events, the natural floodplain serves as a control mechanism in the reduction of downstream flooding. Floodwaters can spread through the floodplain and lead to slower and reduced flows downstream. Accurately identifying and ranking parcels in the study area based on their flood reduction benefit is difficult to achieve even with sophisticated hydrological model results. Flashy hydrologic systems such as the Santa Clara River are difficult to represent with spatial and statistical data because of temporal variability and assumptions necessary for models. Additionally, acquiring data and the expertise to develop this can be challenging. Despite these challenges, using the data and resources that were available, a methodology was developed to identify areas with flood reduction benefits. Flood reduction benefits are defined in this project as areas and/or parcels that redirect floodwaters away from the mainstem of the river, thus diverting some quantity of water out of the floodway and reducing the total volume of water traveling down the system during times of high flow. In order to identify parcels that provide flood reduction benefits, parcels were selected that met the following criteria: 1) Direction: the parcel diverts floodwaters away from the floodway, 2) Holding: it holds floodwaters for some amount of time in the floodplain fringe and 3) Speed: it slows the speed of diverted waters from the floodway.

Hydrology Data

Hydrological data was provided by cbec inc., eco engineering. One dimensional (1-D) and 2-Dimensional (2-D) MIKEFLOOD model results for a 40-mile stretch of the Santa Clara River from the Ventura County Line to the Pacific Ocean were combined by cbec to create the data needed in our analysis. All modeling data was constructed using Q100 peak discharge data provided to cbec from the Ventura County Watershed Protection District's HSPF (Hydrological Simulation Program Fortran) model created in 2009. The entire river was represented by 2-D modeling results except the areas around hydraulic structures, such as bridge crossings, that were represented by the 1-D model. Cbec provided this project with steady state velocity vector and flood height data for a 100-year flood event along the lower Santa Clara River from MIKEFLOOD outputs. Using this data, a hydrological analysis was conducted to identify parcels that provide hydrological benefits.

Parcel Selection

Direction

In order to locate parcels that divert floodwater away from the floodway, a directional magnitude map of the study area was constructed. This was done using velocity vector data for the river and a quiver plot analysis in MATLAB. Quiver plot analysis enables two separate uni-directional velocity vectors to be displayed as one multi-directional magnitude arrow, incorporating x and y flow direction into one vector. This was achieved by taking the 2-D model output which provided U and V velocity components at individual spatial locations throughout the floodplain. This data was uploaded into MATLAB and quiver plot commands were used to create a directional magnitude map. The map consisted of over 180,000 arrows representing floodwater direction and a standardized magnitude at given spatial locations. Figure 6.14 shows directional magnitude vectors for a portion of the southern bank in Fillmore. Vector arrows show that floodwater is being diverted away from the floodway (in yellow) in the circled region. Regions with flows such as these provide floodplain benefits because they reduce flooding volumes downstream for some time period. Areas similar to figure 6.14 were selected throughout the floodplain using the directional magnitude map.

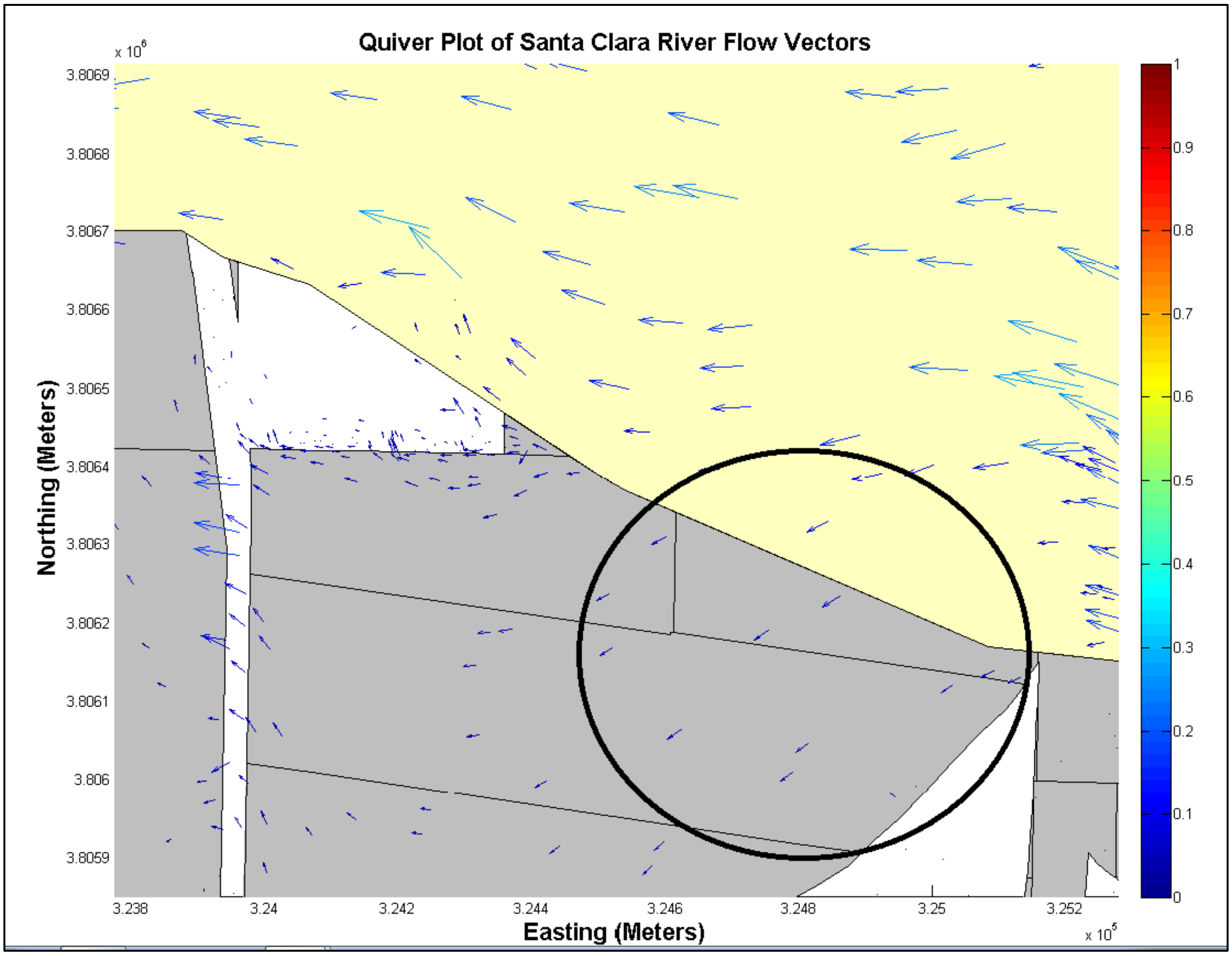

Figure 6.14: Directional magnitude map of a portion of the southern bank of the Santa Clara River near Fillmore, CA. Floodwater is diverting away from the floodway denoted by the circle. Directional magnitude arrows show floodwater velocity to be decreasing after entering the grey area along the floodplain fringe.

Holding

Average parcel volume was derived from compiling MIKEFLOOD flood height data and 2005 LIDAR topographic data. Flood height data represents flood water elevation during a 100-year flooding event. 2005 LIDAR data represented topographic elevation during a period without significant water volumes in the Santa Clara River. In ArcMAP 10.1, flood height data was joined with 2005 LIDAR data representing topographic elevation for each data point in the floodplain. Using the field calculator, the difference between flood height and topographic elevations was derived for 185,011 data points in the study area. This difference represents floodwater height above the river bed. Data points with zero calculations were assumed to be dry in the flood analysis. A spatial join was used to join flood height data to individual parcel polygons. Average height was used to assign each parcel a flood height value throughout the analysis. Using the field calculator, parcel area was multiplied by average parcel flood height to find the average parcel volume per individual parcel in the floodplain. Parcel area in the analysis only represented the portion of a parcel in the 500-year floodplain. Figure 6.15 shows average parcel volumes for a stretch of the Santa Clara River near Fillmore. The area in the black box denotes the location of the area represented in figure 6.14. Average parcel volume allowed parcels to be compared to one another and showed parcels with very little hydrologic storing capacities. Parcels with higher average parcel volumes have the ability to hold more water during large flood events.

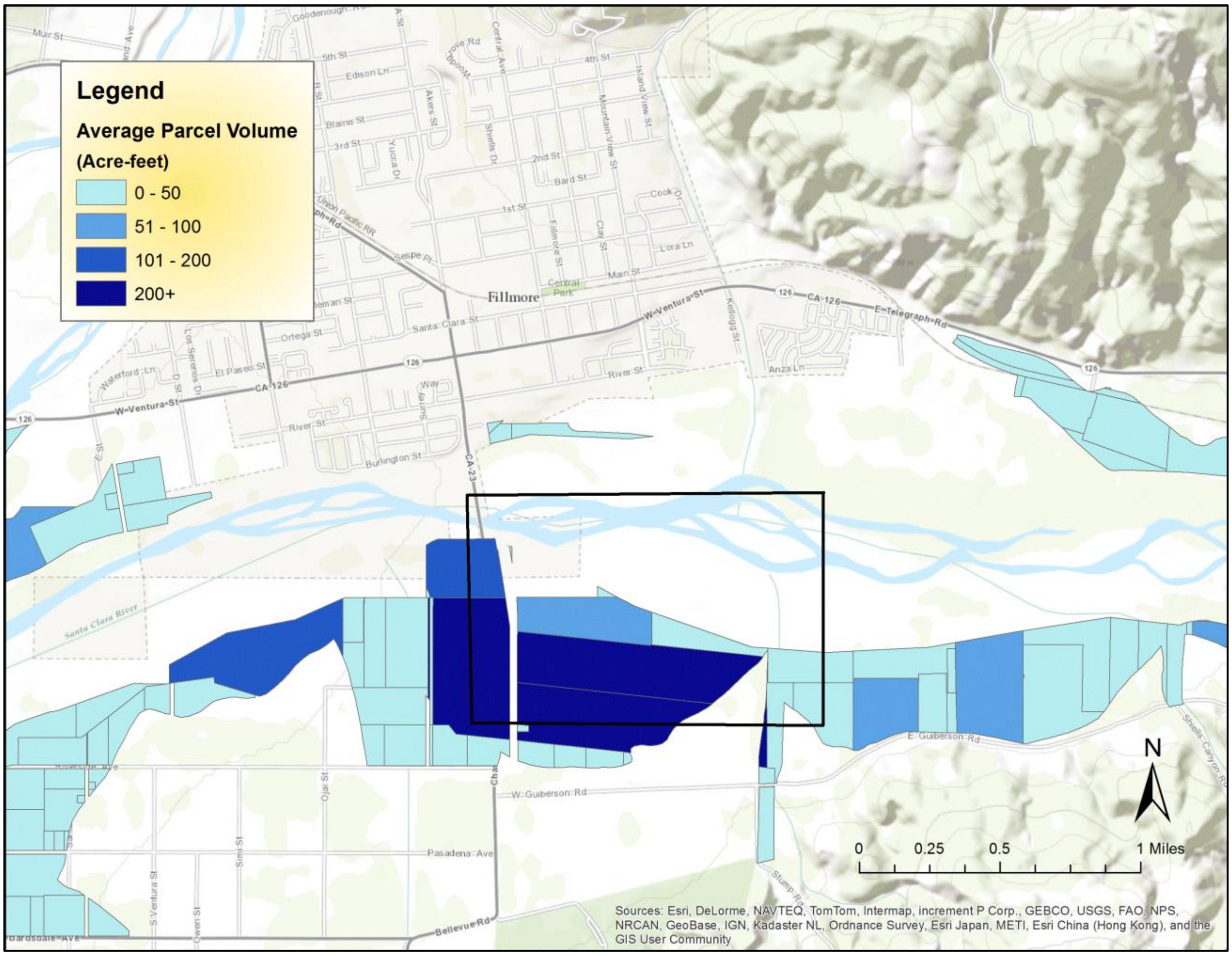

Figure 6.15: Average parcel floodwater volume for parcels located in the 500-year floodplain around Fillmore, CA. Yellow and green parcels hold proportionally less water than orange and red parcels. Parcels with higher average parcel volumes have the ability to hold more water during large flood events. The black box shows figure 6.14 location.

Speed

Average parcel velocity was derived from U,V velocity components of the velocity vector data provided by cbec. Each velocity directional (U,V) component was first squared then those values were summed. The square root of this sum is the velocity of the floodwater at that specific data point.

$$velocity\ of\ floodwater = \sqrt{U^2 + V^2}$$

Floodwater velocity point data was joined to each parcel in the floodplain. Average floodwater velocity for a parcel was used to give each parcel one velocity characteristic. These calculations were performed in MATLAB and joined to existing parcel data in ArcMAP 10.1 for analysis. Having a unitless standardized velocity allowed parcels to be compared to one another and show where floodwater slows down in the floodplain. Figure 6.16 shows an area in Fillmore where flood reduction benefit is occurring. The black box shows were floodwater leaves the floodway and enters the flood fringe (i.e. the area represented in figure 6.14). The water is significantly slowed around the box before it enters back into the floodplain. Areas similar to that in and around the black box are identified throughout the floodplain.

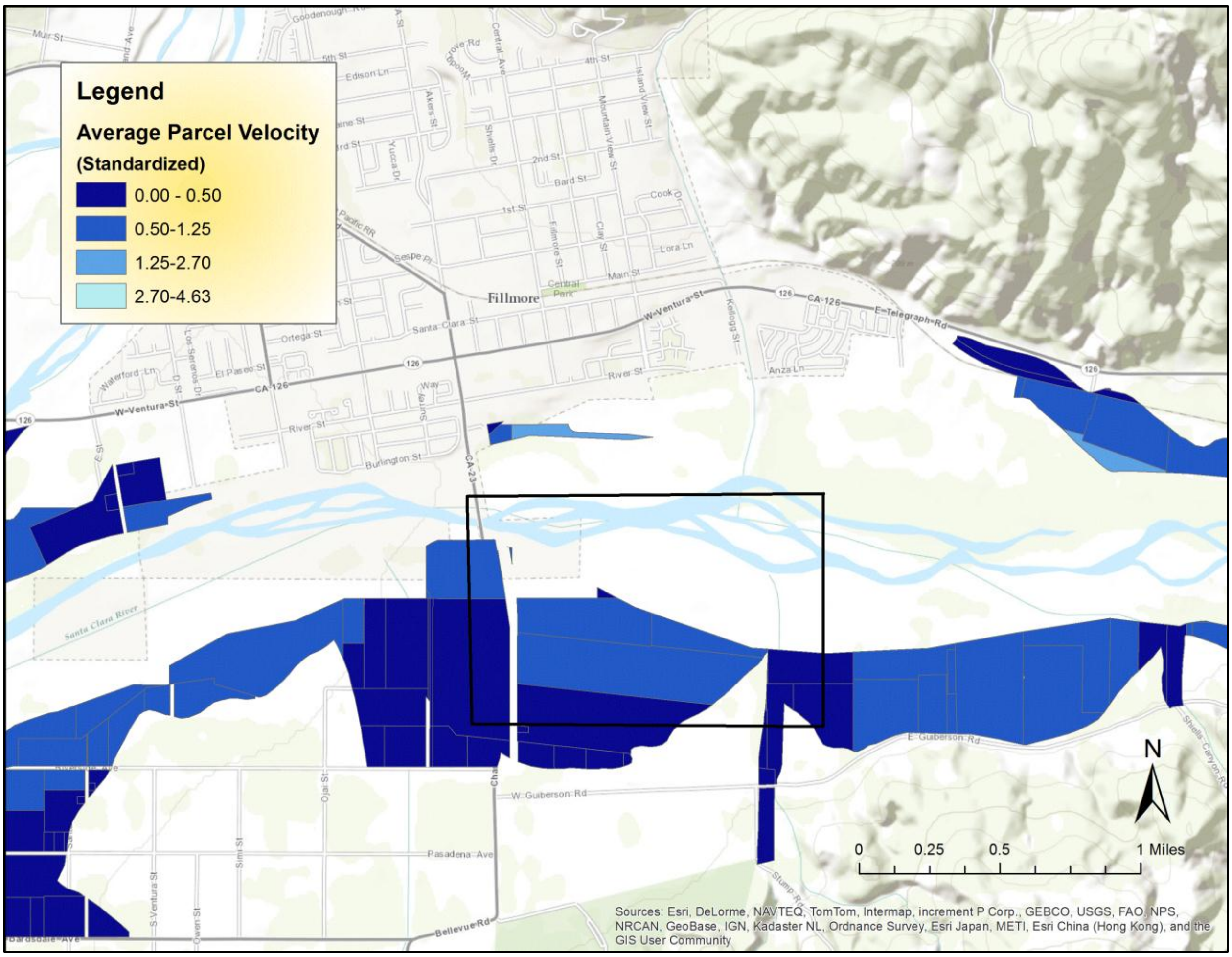

Figure 6.16: Average parcel floodwater velocity for parcels located in the 500-year floodplain around Fillmore, CA. Yellow-green flow pattern shows where floodwater velocity decrease as it enters the floodplain fringe and flood reduction benefit. Darker parcels are more beneficial because of reduced floodwater velocities. The black box denotes Figure 6.14's location.

Selection

Using the directional magnitude arrow map, average parcel velocity, and average parcel volume we identified parcels that could divert, hold, and slow floodwaters in the 500-year floodplain of the Santa Clara River. Parcels were only selected if directional magnitude arrows showed diversion of water away from the floodway into the floodplain fringe, held some volume of water, and decreased the velocities of floodwaters. This methodology was created with expert input from Geomorphologist/Hydrologist Thomas Dunne and Geomorphologist Derek Booth.

6.4 Prioritization of Parcels

Parcel prioritization was done by combining results from the development pressure analyses (WOA and SLEUTH) and flood reduction benefit analysis (Hydrology Analysis). Two sets of prioritization tiers result from this combination. These sets of tiers were compared and parcels that occur in both tier one groupings were designated as top priority parcels. This top priority grouping represents parcels with the highest development pressure that provide downstream flood reduction benefit potential.

6.5 Decision Guidance Tool

Although threat of development and benefit to downstream flood reduction were the only factors considered in the prioritization of parcels for this project, it is understood that additional factors may be relevant in the decision making process for easement acquisition. Additionally, as funding sources and project goals and objectives change in the future, having a comprehensive decision making tool will aid the easement acquisition process. A database has been created that displays not only the results from the prioritization analysis, but also a multitude of additional relevant information on each parcel in the region of interest. The database matrix is found in both a Microsoft Excel spreadsheet and a geo-referenced attribute table in ArcGIS.

Agricultural Characteristics/Considerations

Crop Type

Data on parcel crop type was obtained using parcel site use codes in the assessor's role.

Farmland Monitoring & Mapping Program Designations

The California Department of Conservation's Farmland Monitoring & Mapping Program, rates agricultural lands based on land use, irrigation, and soil quality. Prime Farmland and Farmland of Statewide Importance designations are given to agricultural lands that meet specified criteria. Data on farmland designations in the ROI was obtained from the Farmland Mapping & Monitoring Program website.

Ecological Characteristics/Considerations

Conservation Priorities

The 2008 Conservation Plan for the Lower Santa Clara River Watershed and Surrounding Areas established conservation targets for TNC that led to prioritizing tracts for conservation along the Santa Clara River. These targets included coastal communities, riparian forest and scrub communities, grasslands, coastal scrub communities, oak woodlands, chaparral communities, aquatic vertebrates, and wide ranging terrestrial vertebrates. Parcels were later tiered based on size, ownership, habitat characteristics, conservation target potential, connectivity to protected areas and wildlife linkages, and threats. Data on specific spatial conservation priority tracts was provided by TNC.

Wildlife Linkages

South Coast Wildlands' South Coast Missing Linkages project identified important habitat corridors between the fragmented natural areas still remaining in Southern California. TNC in their Lower Santa Clara River Watershed and Surrounding Areas Conservation Plan identified protecting these linkages as a conservation target. These corridors serve as important ecological linkages in Southern California and are essential for survival of many wide-ranging species. Spatial data representing these linkages was obtained from the South Coast Missing Linkages project via TNC.

Rare, Threatened, and Endangered Species Habitat

The Santa Clara River Watershed is home to 117 rare, threatened, and endangered plant and animal species. The conservation targets of TNC's Conservation Plan for the Lower Santa Clara River Watershed and Surrounding Areas addresses the conservation need for many of these species of concern. Data on species extent and listed habitats was obtained from the California Natural Diversity Database and the US Fish & Wildlife Service Critical Habitat Portal.

Invasive Species Density

Invasive species have become a major ecological concern for riparian habitat within the Santa Clara River Watershed. Giant Reed (*Arrundo donax*) is the main concern within the watershed and the project's ROI. This tall, hardy, fast-growing species, similar to bamboo, has already invaded much of the riparian habitat of the watershed. Spatial data on percentage of *Arrundo donax* cover was obtained from the California Invasive Plant Council.

Adjacency to Existing Conservation Properties

Conservation organizations like TNC and Friends of the Santa Clara have already purchased properties along the Santa Clara for conservation. Placing easements on parcels adjacent to these already protected properties will help create larger contiguous protected areas, which will be beneficial to native wildlife. The assessor's role was used to identify parcels already owned by conservation organizations and their adjacent parcels.

Additional Parcel Characteristics/Considerations

Land Conservation Act Status and Contract Expiration Date

In 1965 California passed the Land Conservation Act (LCA), also known as the Williamson act, to help preserve the state's agricultural and open space lands. Properties under LCA contracts are protected from development until the owner decides to not renew the contract. LCA contracts several years after non-renewal. Data on current LCA contracts and expirations was obtained from the VCPD.

Factors from Prioritization

In addition to these factors, the decision guidance database also includes ranking and scoring results from the WOA and SLEUTH models respectively, tiered results from combination of hydrological analysis and development pressure models, and the top priority parcels.

6.6 Easement Valuation

Agricultural Conservation Easements (ACEs) purchased by The Nature Conservancy in the Santa Clara River floodplain will allow for continued agricultural production and limit future development of a property. Up to this point, there have been no ACEs sold in Ventura County, meaning that there is no accepted price for ACEs in the Santa Clara River floodplain. Because of this, The Nature Conservancy requested a preliminary valuation of ACEs in the floodplain.
To evaluate the price to be paid for an ACE, the value of the development right had to be determined. To do this, four simple methodologies were used to extract the value of future development from the total value of the property. The resulting range of values will be used by TNC to determine a fair price with which to compensate property owners in the floodplain for their future development rights.

Method 1: Income Capitalization

Income capitalization uses the Net Present Value (NPV) of agricultural leases to determine the value of agriculture on the land. It assumes that the market has incorporated some likelihood of future development into the price of the property. The value of agriculture is then subtracted from the fair market value of the land (i.e. fee simple purchase). The residual is the value of the development rights (VDR) of the property.

$$VDR = Fair\ Market\ Value - NPV\ Ag\ Leases$$

Estimates for both the lease rates and the Fair Market Value of properties along the Santa Clara River were obtained from local agricultural appraisers. Lease rates and land values varied along the river and decreased in value further from the ocean. Three different discount rates (i.e. 3%, 5%, & 7%) were used to calculate the net present value of agricultural leases. Agricultural rental rates were assumed to remain the same.

The following two discounting techniques were used to determine the NPV of Ag Leases: (1) (Agricultural Rental Rate) / (discount rate), (2) summation of the discounted Ag leases 100 years into the future.

Method 2: Sales Comparison

The sales comparison approach uses the fair market value of two similar properties that differ greatly in development pressure. To calculate the value of development rights, the value of the parcel with low development pressure was subtracted from the value of the parcel with high development pressure.

$$VDR = Fair\ Market\ Value(high\ development\ pressure) - Fair\ Market\ Value(low\ development\ pressure$$

Based on similar rankings of total agriculture value by county, similar average net income per farm (USDA Census of Agriculture), and conversations with agricultural appraisers throughout the state, the following counties were used for sales comparisons: Kern, Monterey, Stanislaus, San Joaquin, Santa Barbara, and Madera. For all comparisons, it was assumed agricultural value was similar to Ventura County and development pressure was nearly zero in the counties used for comparison. Data on property values were gathered from the USDA Census of Agriculture, local farmer estimates, and the 2012 Trends report from the California Chapter of the American Society of Farm Managers and Rural Appraisers.

Method 3: ACE Comparisons

The California Farmland Conservancy Program (CFCP) funds programs to purchase agricultural easements throughout the state. All of their funded easements are collected in a public database with information about the appraised easement value and defining characteristics of the property, including location and crop type. CFCP easement information was used to find properties that were similar to those in the Santa Clara River floodplain in location, population pressures, and agricultural production values. The prices of these easements were then averaged and an estimate of easement value was obtained.

Method 4: Discounted Value of the Development Right

This method looked directly at the value of the development right of a parcel and examined the range of values that would result from various time horizons of future development at various discount rates.

The theory behind this method is that the value of land from an already developed parcel can only be attributed to the value of the development right, assuming that right is exercised today. By discounting this value to some predicted date of development, we can determine the NPV of the development right of a similar, undeveloped, parcel. We can then subtract from this the expected NPV of agriculture to determine the necessary compensation to be paid to the landowner to remove that development right.

$$VDR = \frac{DLV}{(1+r)^t} - \frac{Ag\ Rent}{(1+r)^t}$$

Where r = discount rate, t = year of conversion, DLV = developed land value.

Developed land values were determined using data from the Ventura County Assessor. Three discount rates were used (3%, 5%, & 7%), and time horizons between 25 and 100 years were examined. Agricultural rental rates were assumed to remain the same.

7. Results

Result Maps

The results of both development models, the SLEUTH urban growth model and the Weighted Overlay Analysis (WOA), can be found below. For ease of viewing parcels and their associated development pressures, the region of interest (ROI) has been broken up into six regions, which are displayed separately throughout the results section. Three of these maps depict the main tributaries (Santa Paula Creek, Sespe Creek, and Piru Creek), and the other three depict regions of the lower Santa Clara River (Ventura region, Santa Paula region, and Fillmore region) See (Figure 7.1 & Figure 7.2)

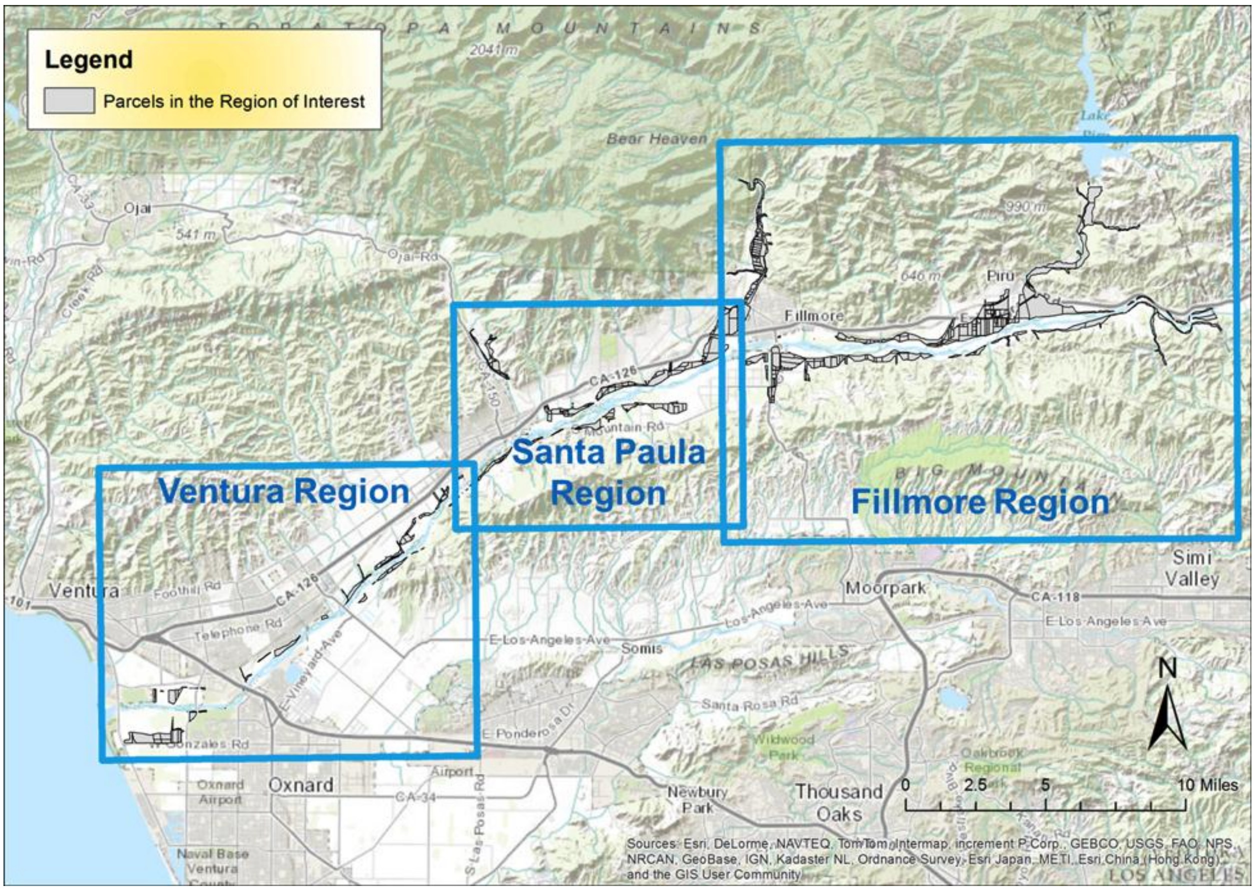

Figure 7.1: Three regions of the mainstem of the Santa Clara River depicted in the results.

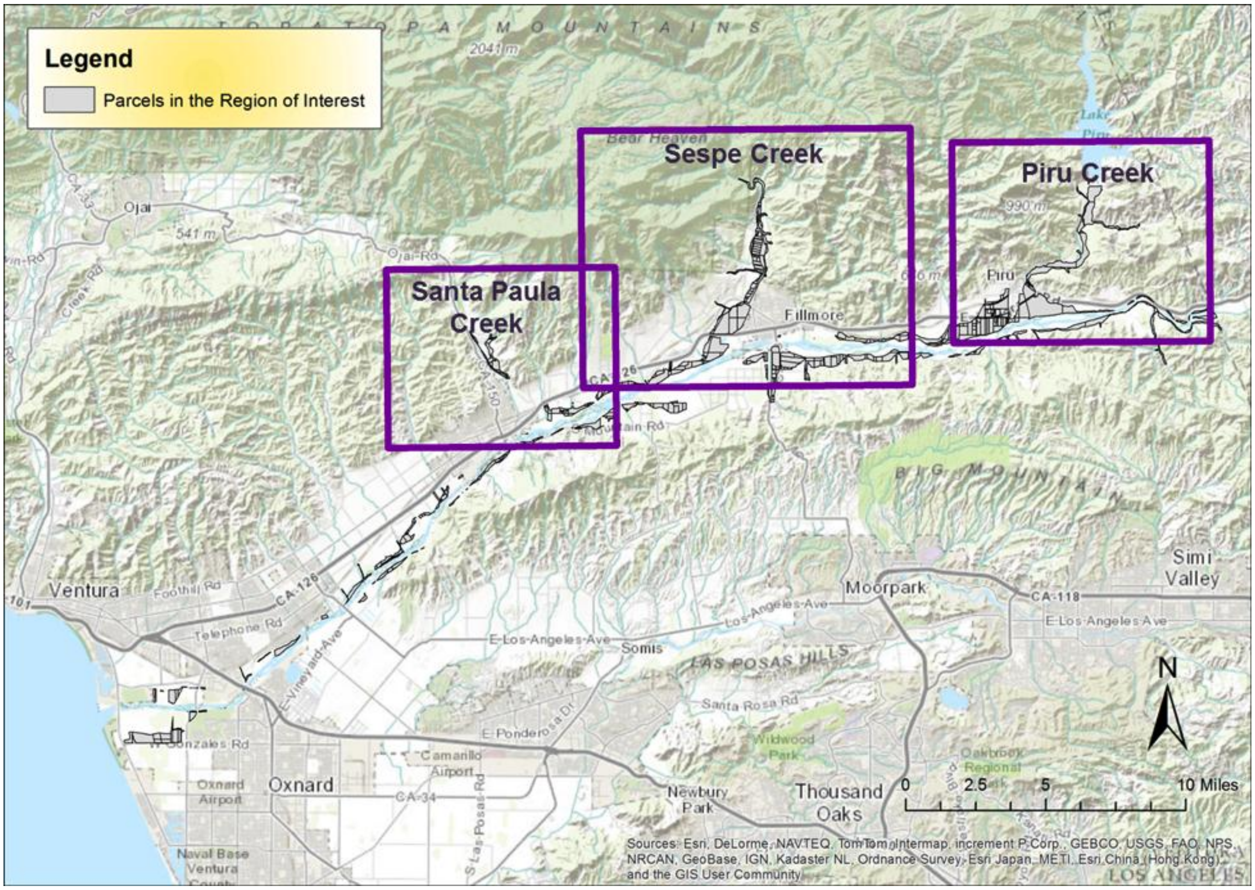

Figure 7.2: Three tributaries of the Santa Clara River depicted in the results.

7.1 Weighted Overlay Analysis

The WOA model was created to ordinally rank parcels in the ROI. The input layers of the WOA included county zoning and general plan land use designation, proximity to urban growth boundaries, parcel size, floodplain designation, proximity to major roads, proximity to local roads, and proximity to levees. In all model results, high scores represent parcels with higher development pressure while low scores represent parcels with lower development pressure. The WOA model allows for parcels to be compared to one another in an ordinal ranking system.

Santa Clara River Mainstem

The WOA model ranked 485 parcels in the ROI along the Santa Clara River's mainstem. Parcel scores ranged from 1.29 to 3.29 with a mean and median score of 2.06 (See Figure 7.3). The highest frequency of scores occurred around the mean while the lowest frequency occurred above 2.8. No strong trend was observed in the data to describe the distribution of scores along the mainstem.

The ten highest ranked parcels had scores between 2.901 and 3.286. Parcels located on Piru's eastern city boundary, Fillmore's western city boundary, Santa Paula's entire city boundary, Saticoy's western city boundary, and parcels adjacent to the river along the Ventura City boundary had the highest WOA scores (See Figures 7.4-7.6). The highest scored parcels were parcels with large acreage, those that were close to current urban growth boundaries, and had favorable zoning designations.

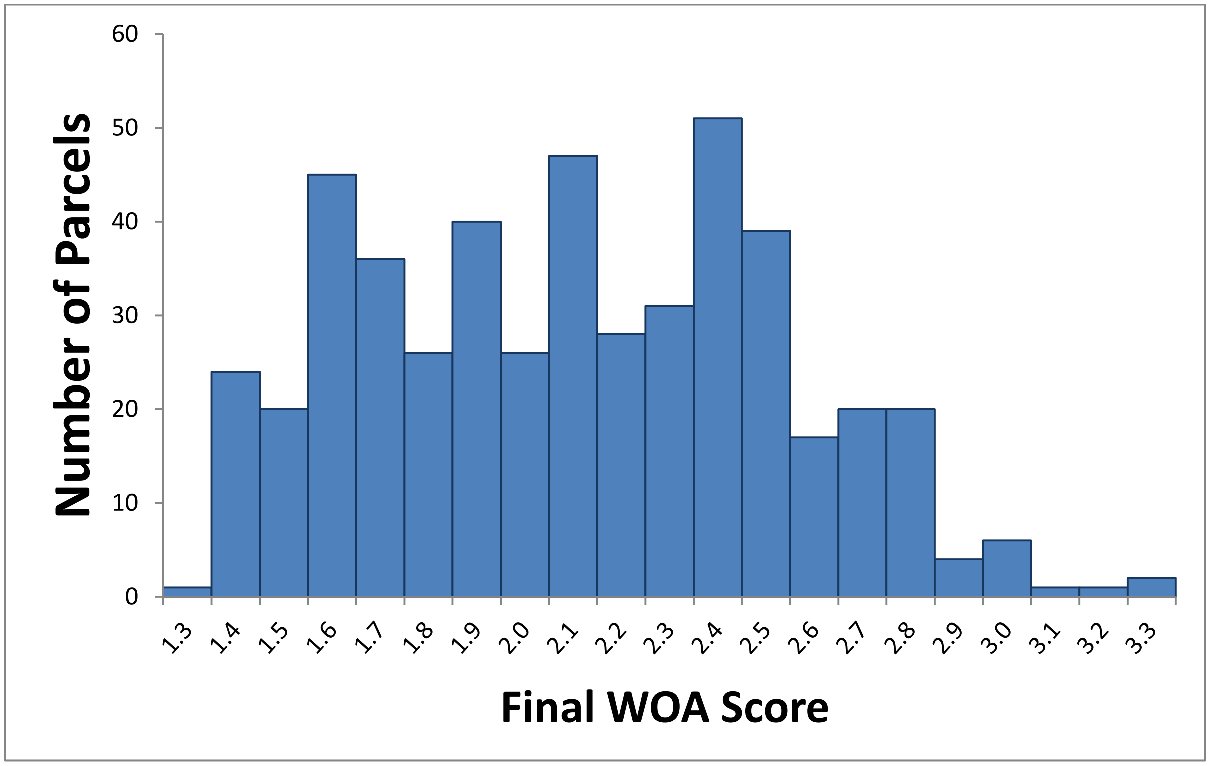

Figure 7.3: Frequency distribution of the number of parcels and WOA score in the region of interest along the mainstem

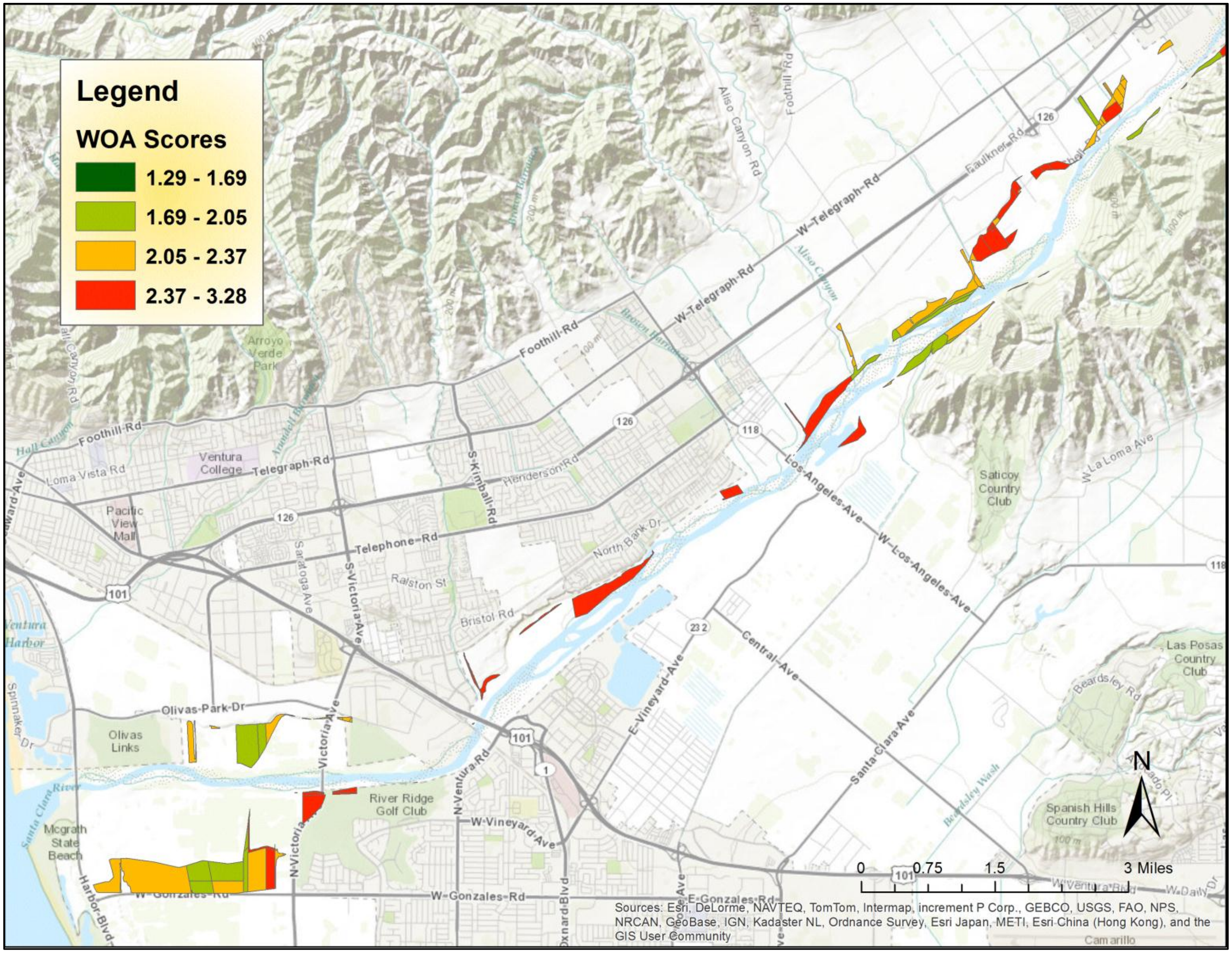

Figure 7.4: WOA scores the in Ventura Region for the Santa Clara River mainstem. Red indicates high development pressure while green indicates low development pressure.

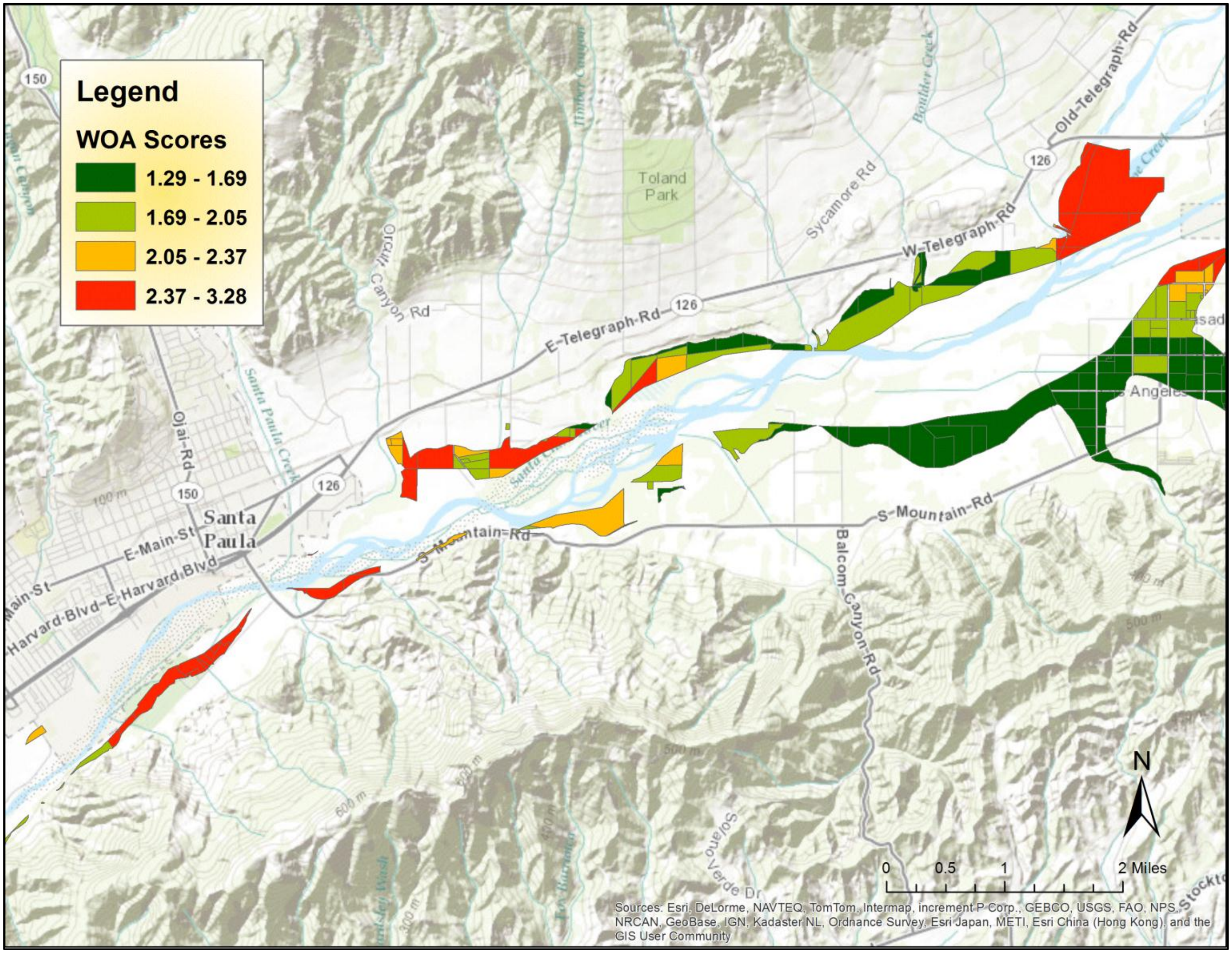

Figure 7.5: WOA scores in the Santa Paula Region for the Santa Clara River mainstem. Red indicates high development pressure while green indicates low development pressure.

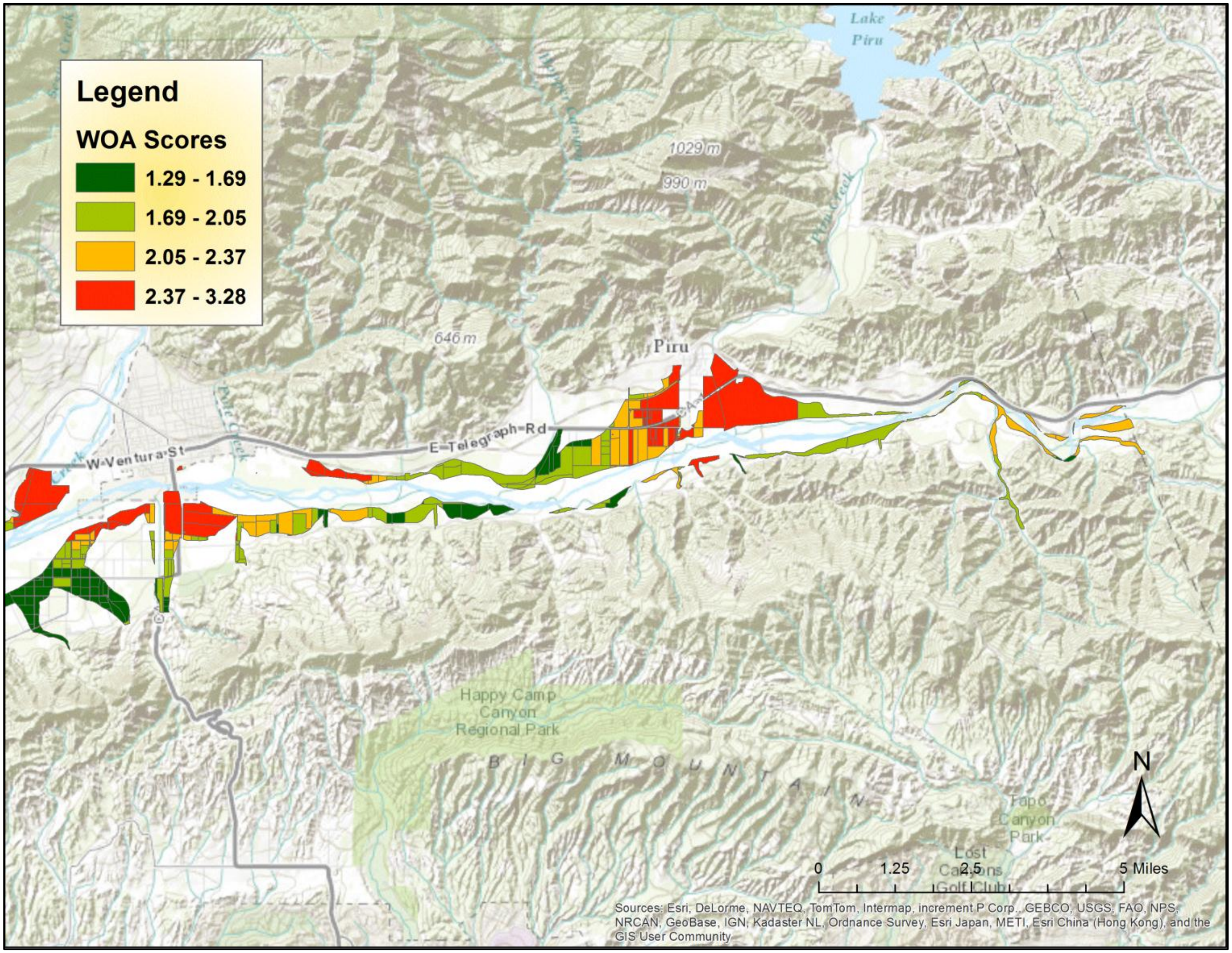

Figure 7.6: WOA scores in the Fillmore Region for the Santa Clara River mainstem. Red indicates high development pressure while green indicates low development pressure.

Santa Clara River Tributaries

The WOA ranked 193 parcels located in ROI along Santa Paula Creek, Sespe Creek, and Piru Creek. Parcel scores ranged from 1.27 to 3.32 with mean and median scores of 2.10 and 2.00 respectively. The ten highest ranked parcels had scores between 3.05 and 3.32 (See Figure 7.7). Parcels located near Santa Paula Creek had high WOA scores. Parcels located along Sespe Creek had a large range of WOA scores; the highest scores occurred on large parcels bordering Fillmore's urban growth boundary. All the parcels along Piru Creek had high WOA scores. The highest scores along Piru creek were parcels located closest to Piru's urban growth boundary; parcel scores decrease as distance from Piru's urban growth boundary increases (See Figures 7.8-7.10).

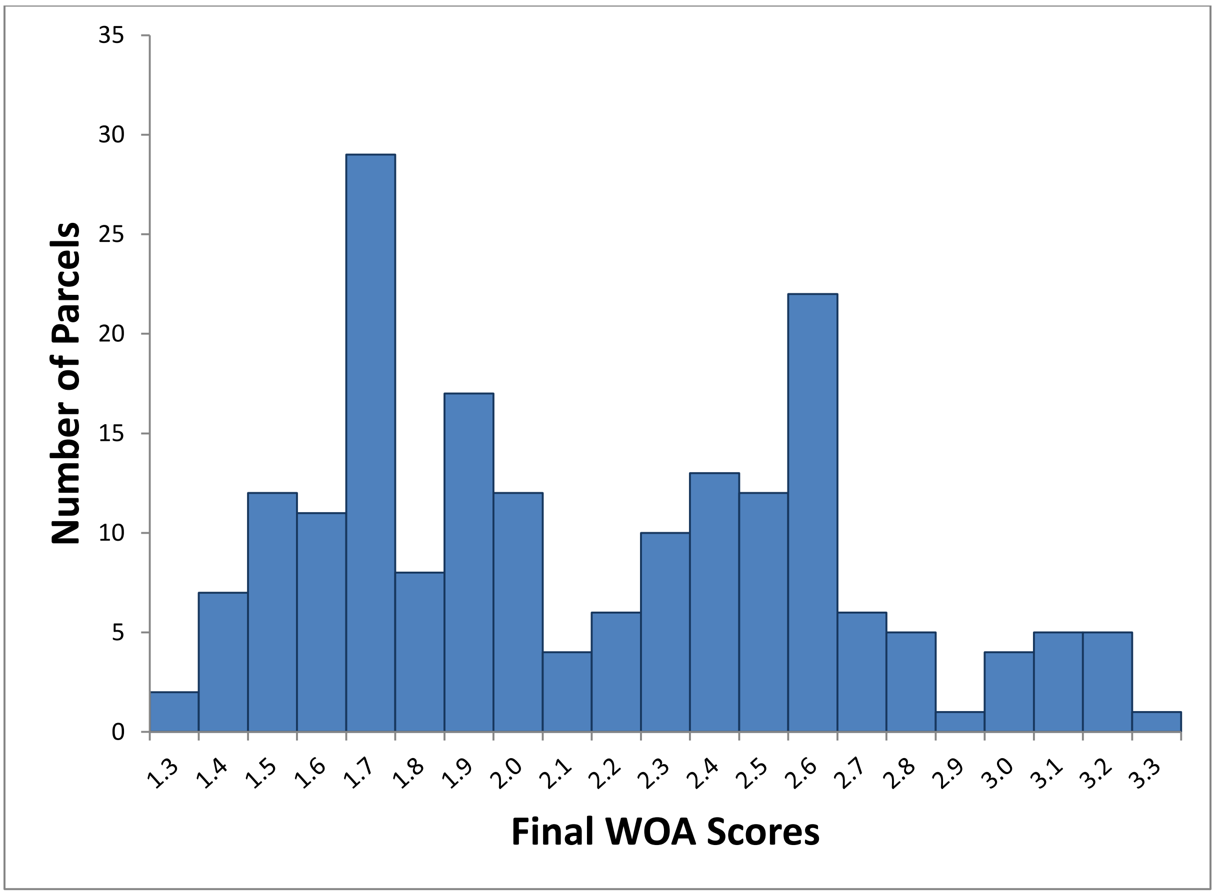

Figure 7.7: Frequency distribution of the number of parcels and WOA score in the region of interest along the tributaries

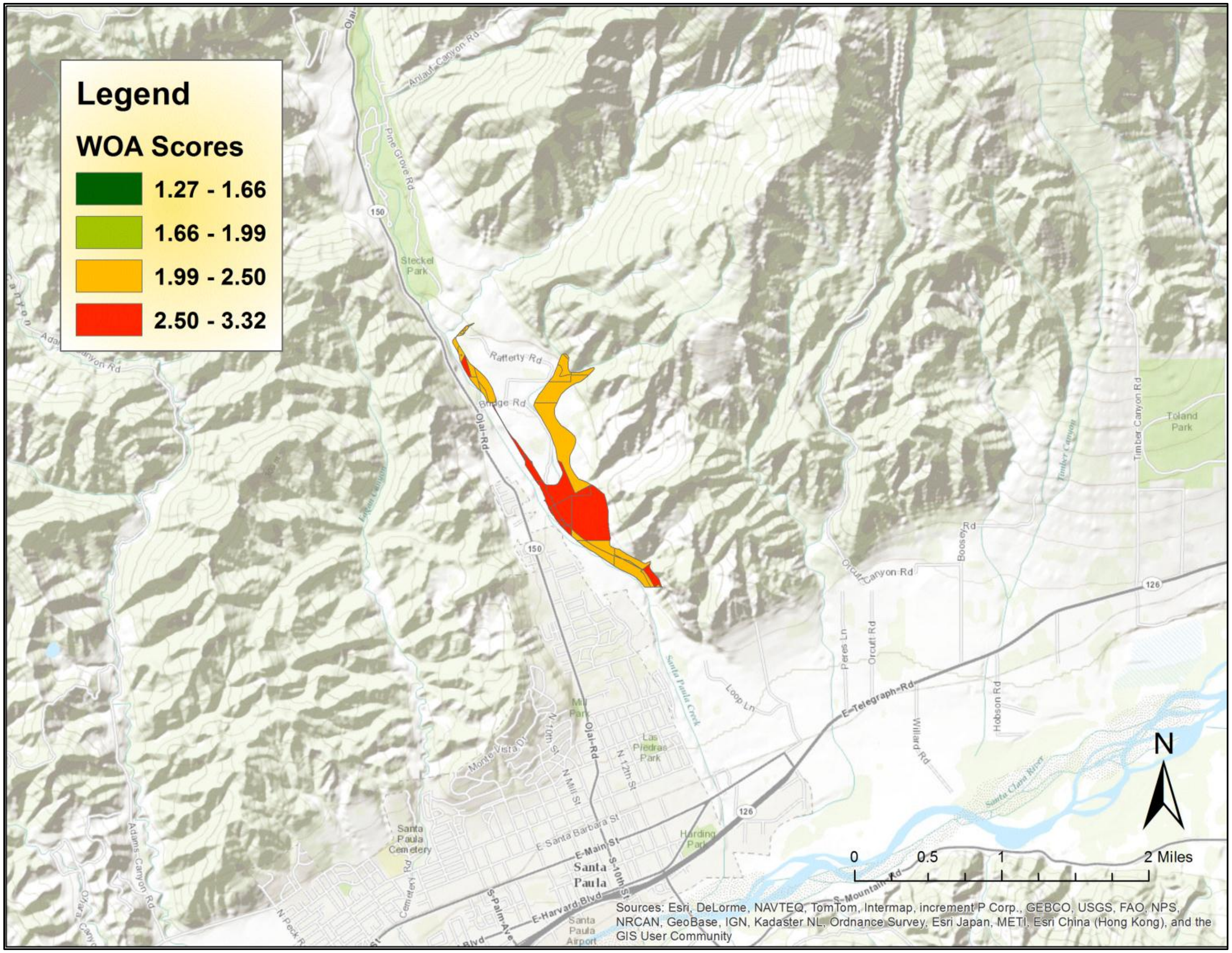

Figure 7.8: WOA scores for Santa Paula Creek Region. Red indicates high development pressure while green indicates low development pressure.

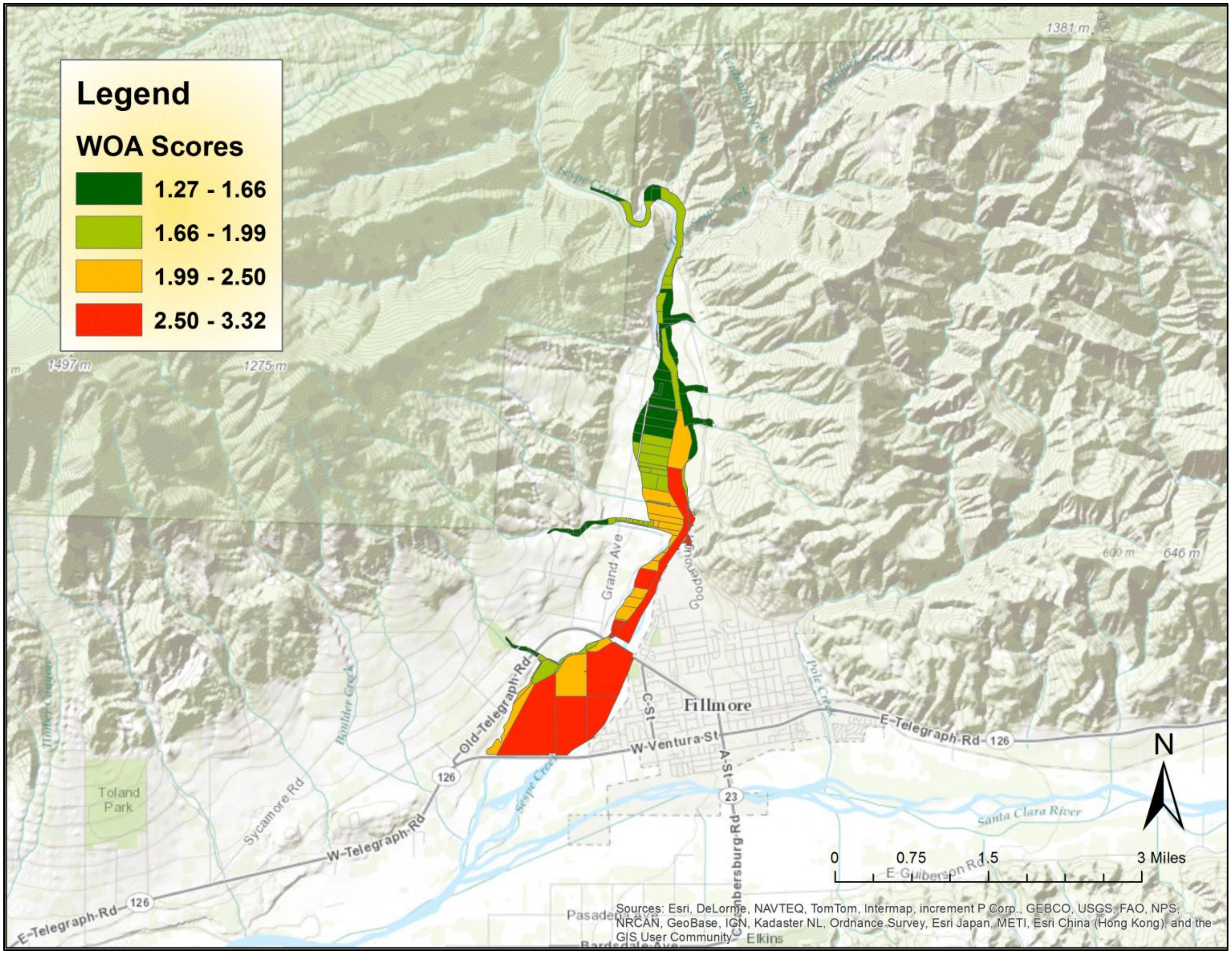

Figure 7.9: WOA Scores for Sespe Creek Region. Red indicates high development pressure while green indicates low development pressure.

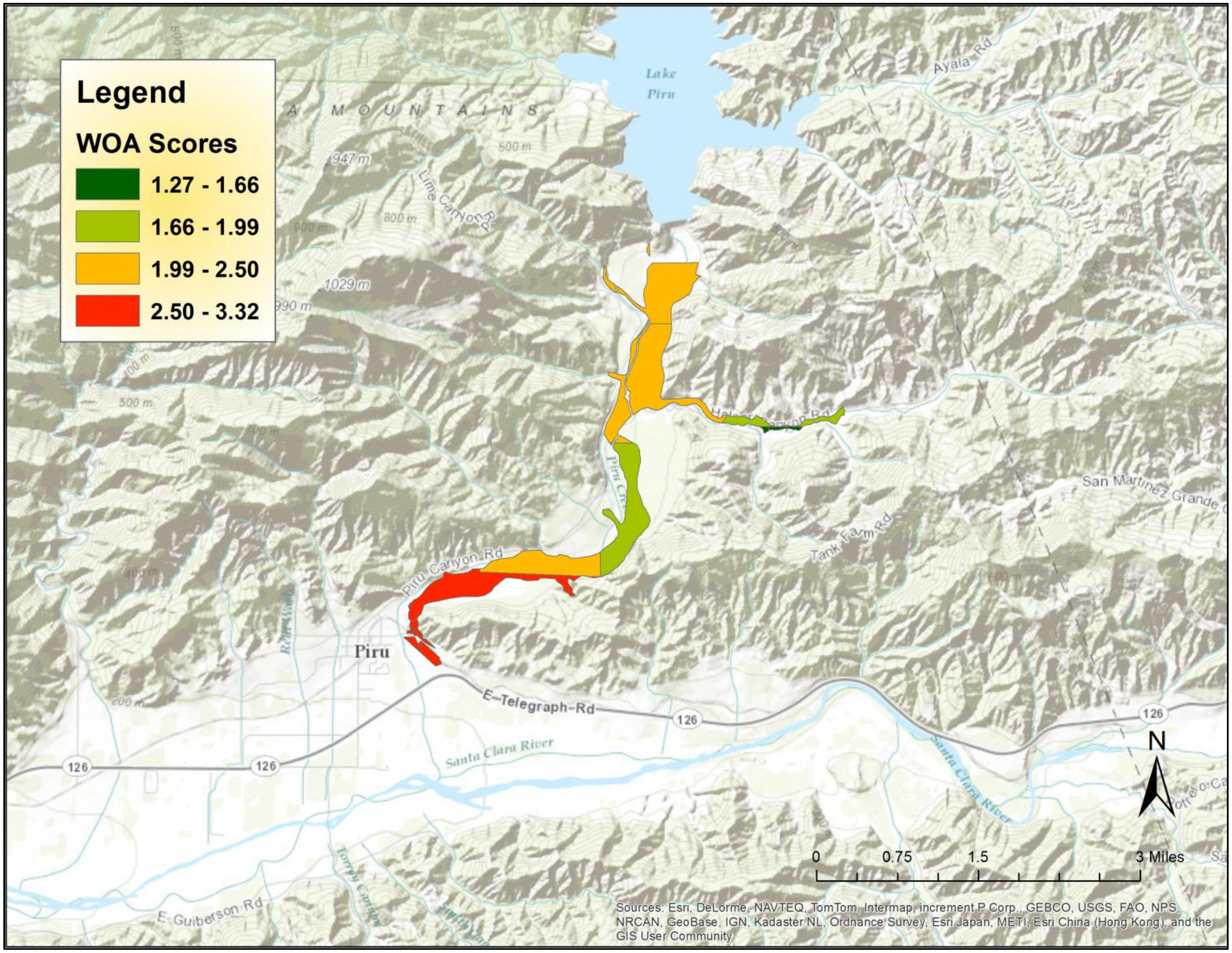

Figure 7.10: WOA Scores for Piru Creek Region. Red indicates high development pressure while green indicates low development pressure.

7.2 SLEUTH

The following results for the SLEUTH model are from the primary exclusion scenario in which the zoning exclusion layer was used. The two other exclusion scenarios are described in the discussion section.

Santa Clara River Mainstem

For the SLEUTH model, 62 percent of parcels in the region of interest (ROI) along the mainstem of the Santa Clara River had a 5 percent or greater probability of being converted to urban development in the next 50 years (by 2063). Approximately 31 percent of the ROI parcels had a 30 percent or greater chance of being converted during the same period of time. A frequency distribution depicting the number of parcels and their likelihood of development can be found in Figure 7.11.

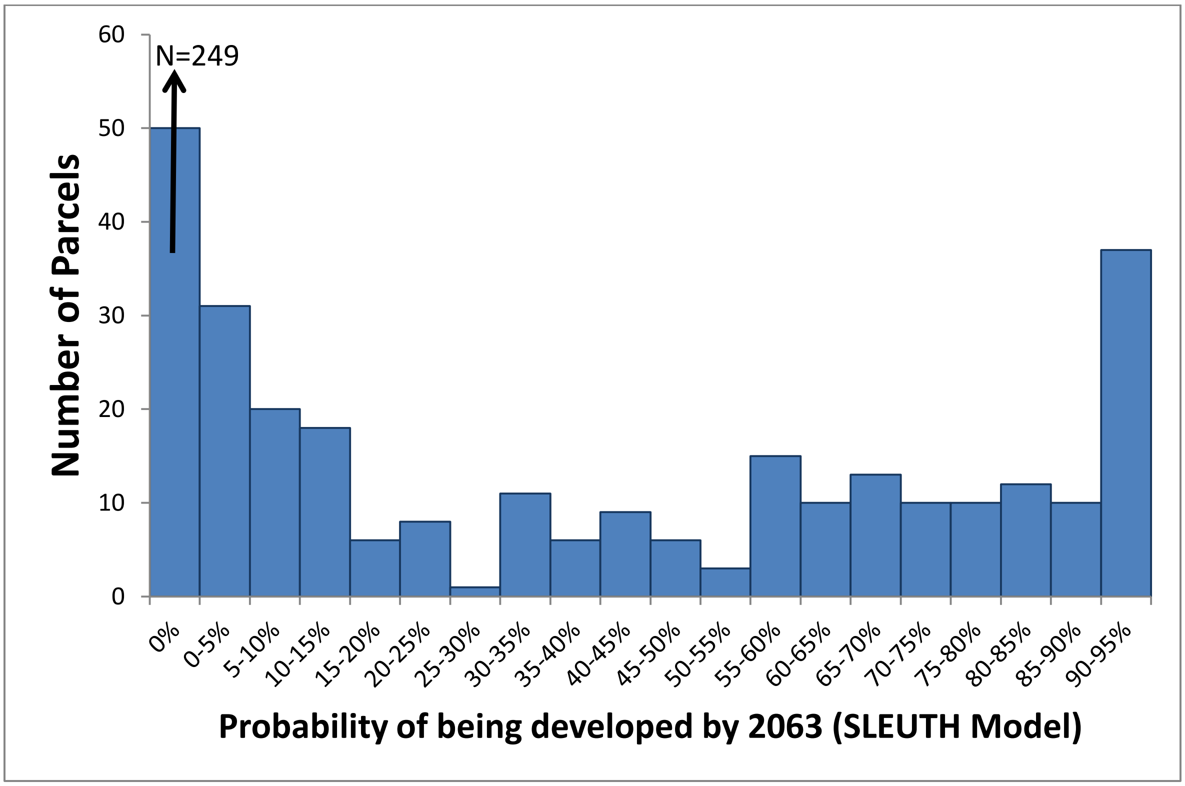

Figure 7.11: Frequency distribution of the number of parcels and their likelihood of development in the region of interest along the mainstem of the Santa Clara River.

There were 37 parcels of the 485 parcels in the mainstem ROI that were found to be nearly certain of be developed in the next 50 years with development probabilities between 90 percent and 95 percent.

The following three maps depict each region of the mainstem of the River and the associated development probability by 2063 according to the SLEUTH model (See Figures 7.12-7.14)

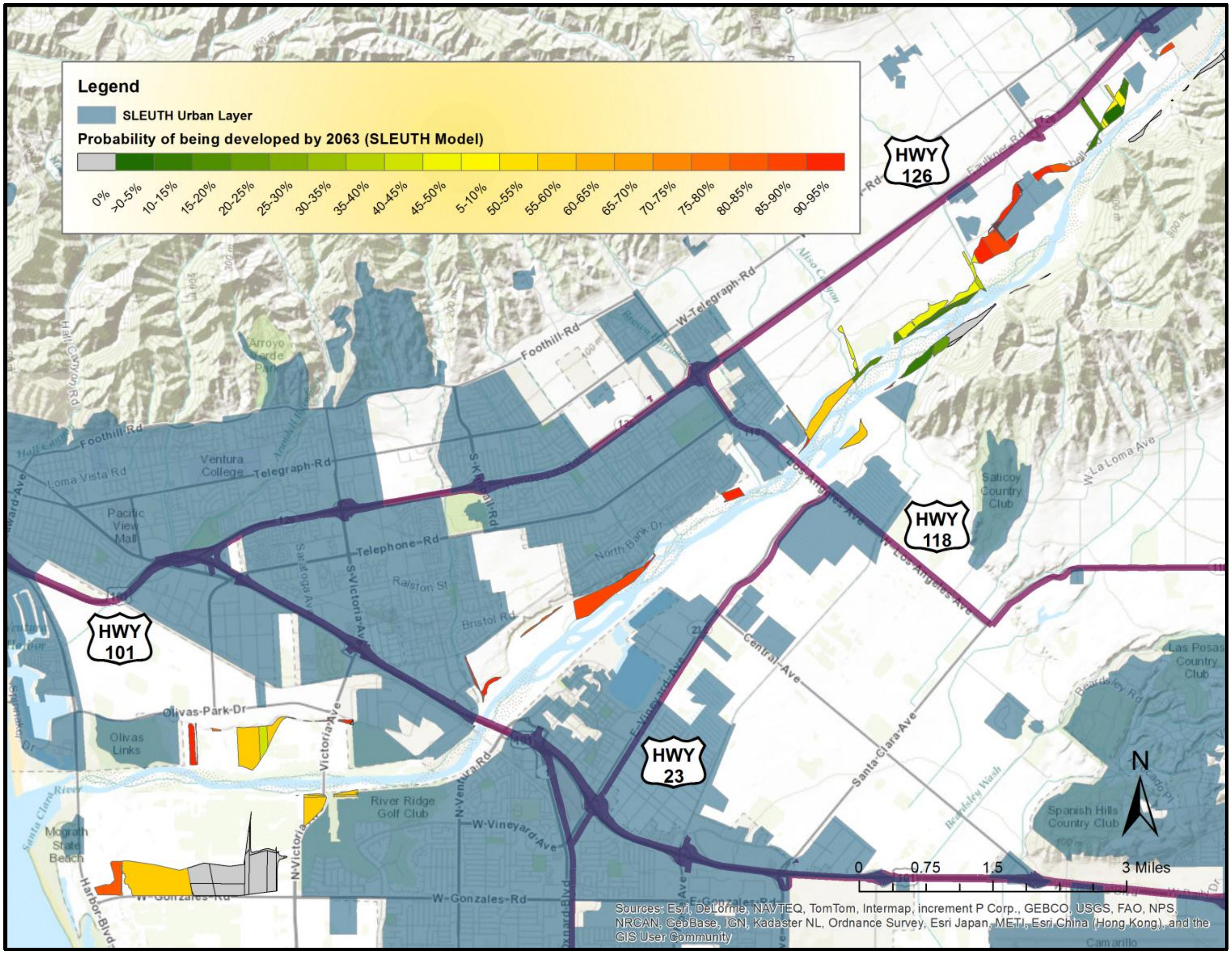

Figure 7.12: Region of interest parcels located in the Ventura Region and their associated probability of being developed by 2063 according to the SLEUTH model

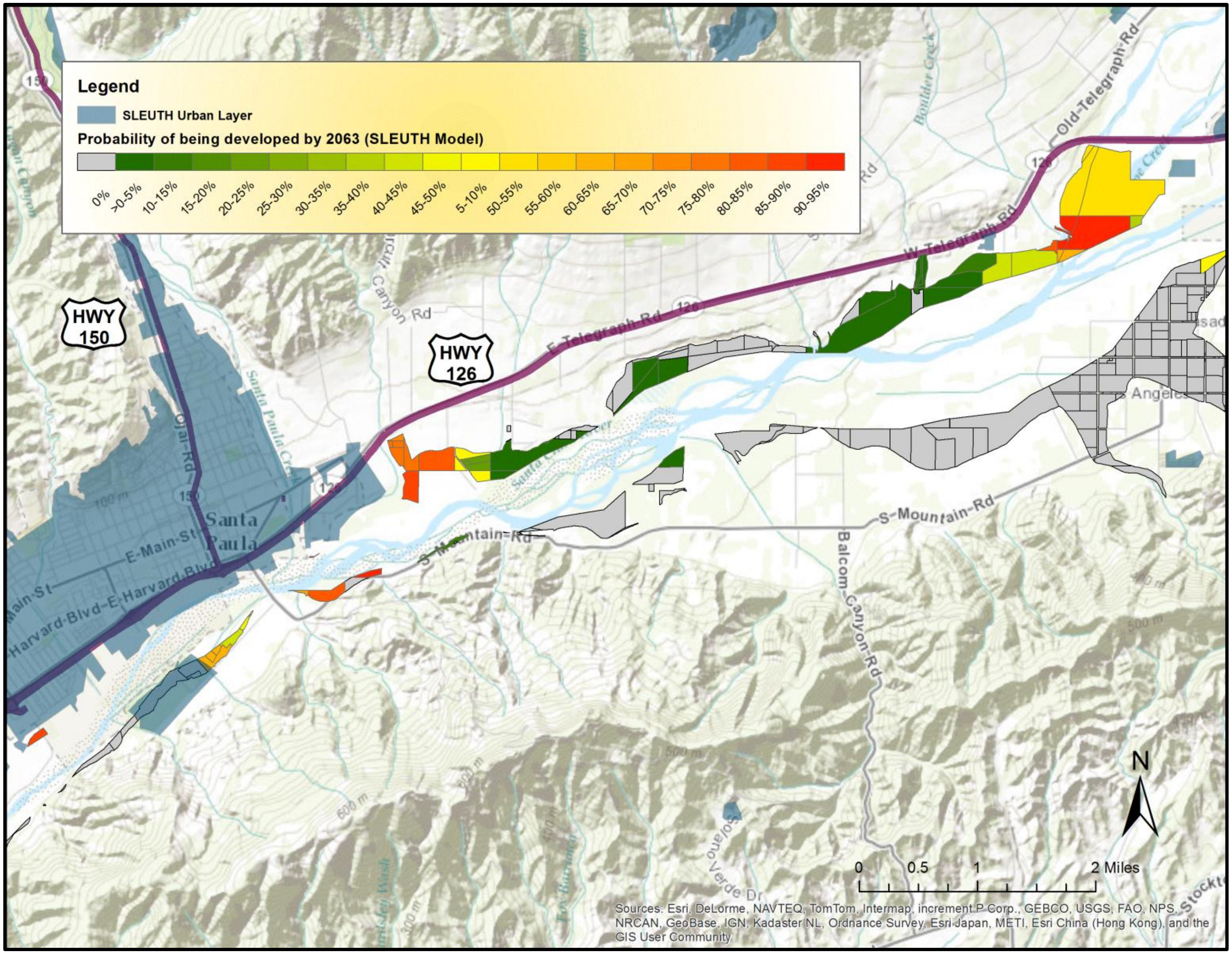

Figure 7.13: Region of interest parcels located in the Santa Paula Region and their associated probability of being developed by 2063 according to the SLEUTH model

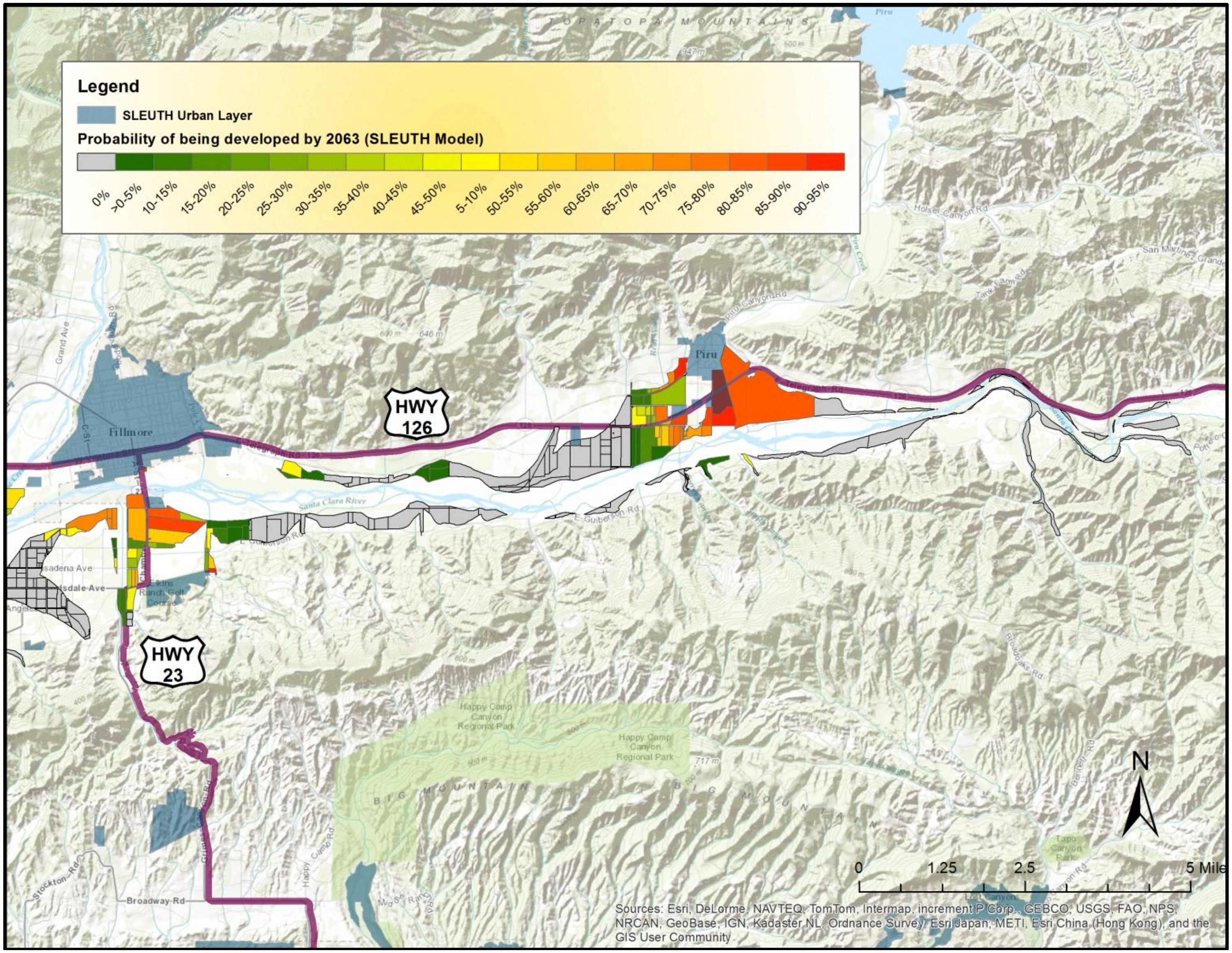

Figure 7.14: Region of interest parcels located in the Piru and Fillmore Region and their associated probability of being developed by 2063 according to the SLEUTH model

Santa Clara River Tributaries

The SLEUTH model found that 57 percent of the parcels in the region of interest (ROI) along the tributaries had greater than 5 percent probability of being converted to urban land uses in the next 50 years (by 2063). Approximately 35 percent of the ROI tributary parcels had greater than 30 percent chance of being developed during the same period of time. Thirty-two of the 193 parcels in the tributaries ROI were found to be nearly certain to be developed in the next 50 years with probabilities of development between 90 percent and 95 percent. A frequency distribution depicting the number of parcels and their likelihood of being developed can be found in Figure 7.15.

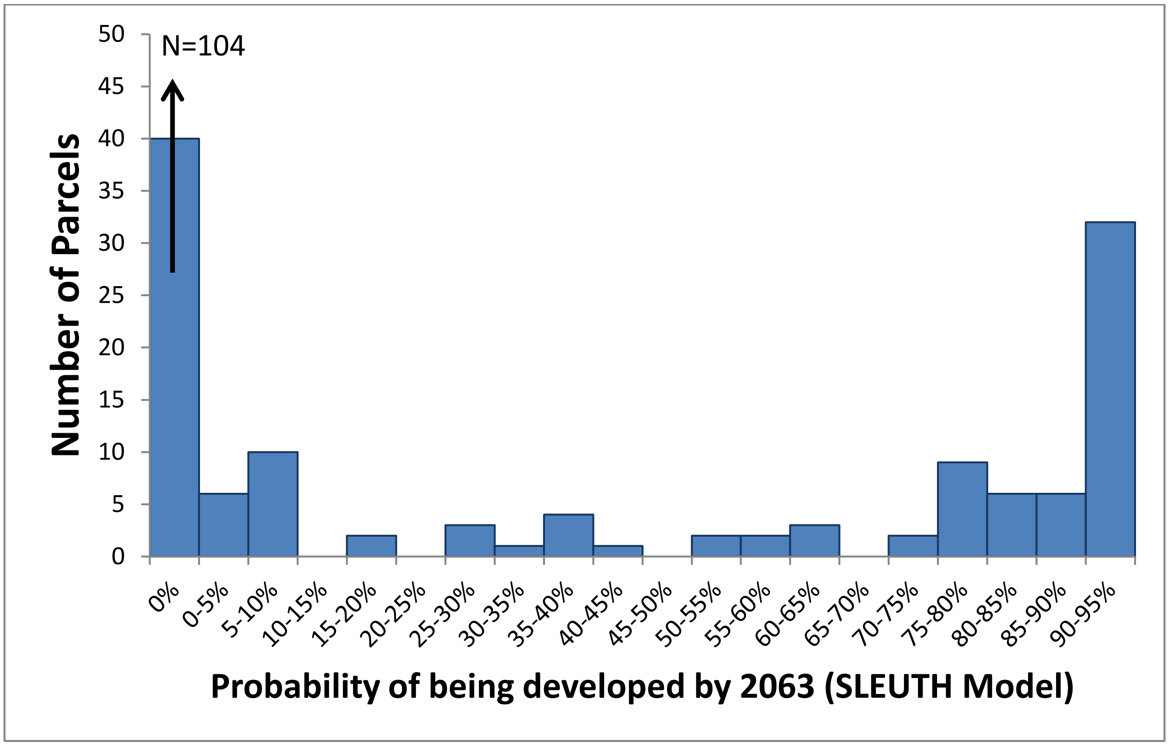

Figure 7.15: Frequency distribution of the number of parcels and their likelihood of development according to the SLEUTH model in the tributaries ROI

The following three maps depict each tributary region of the Santa Clara River and the associated probability of being developed by 2063 according to the SLEUTH model (See Figures 7.16-7.18).

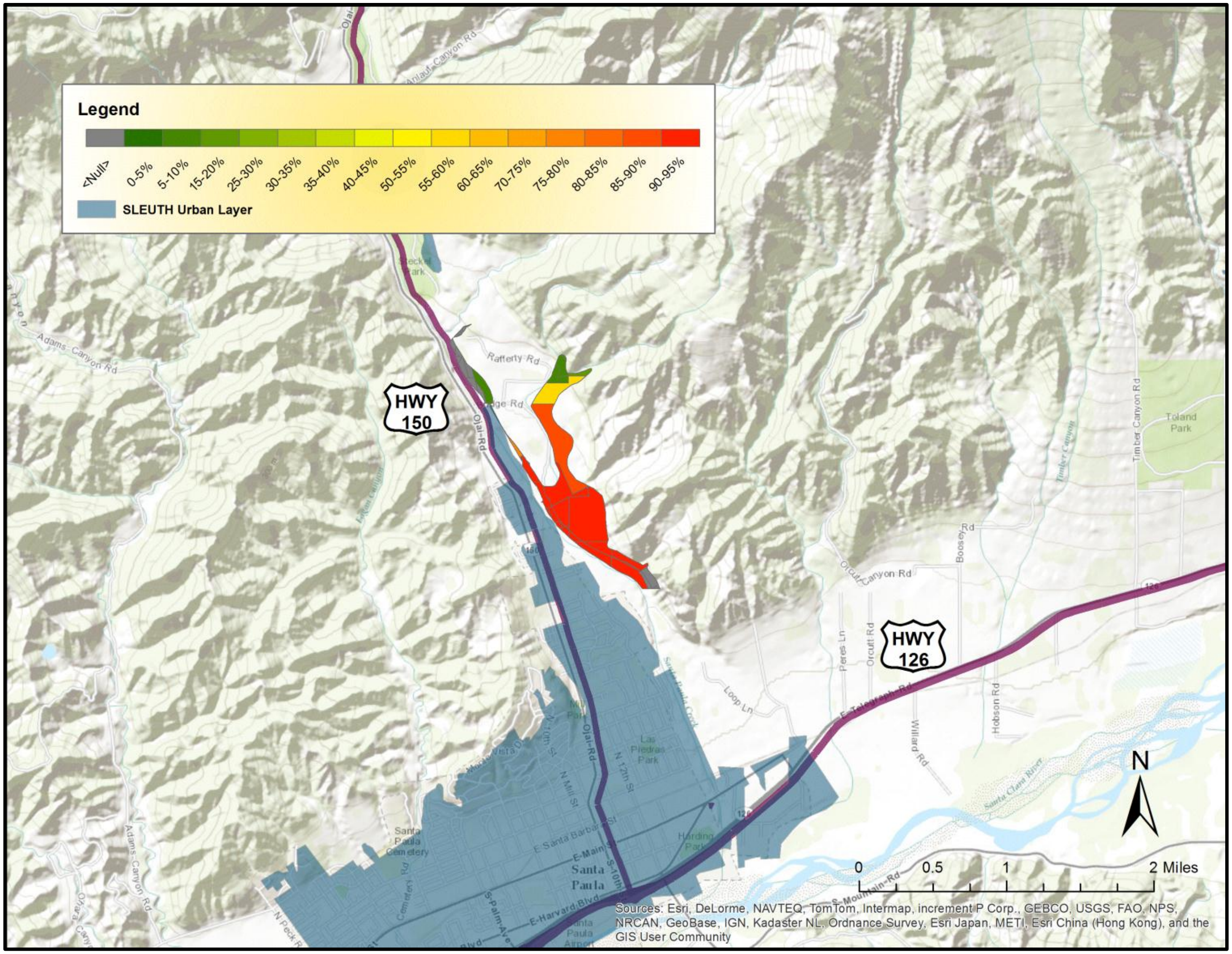

Figure 7.16: Region of interest parcels along Santa Paula Creek and their associated probability of being developed by 2063 according to the SLEUTH model

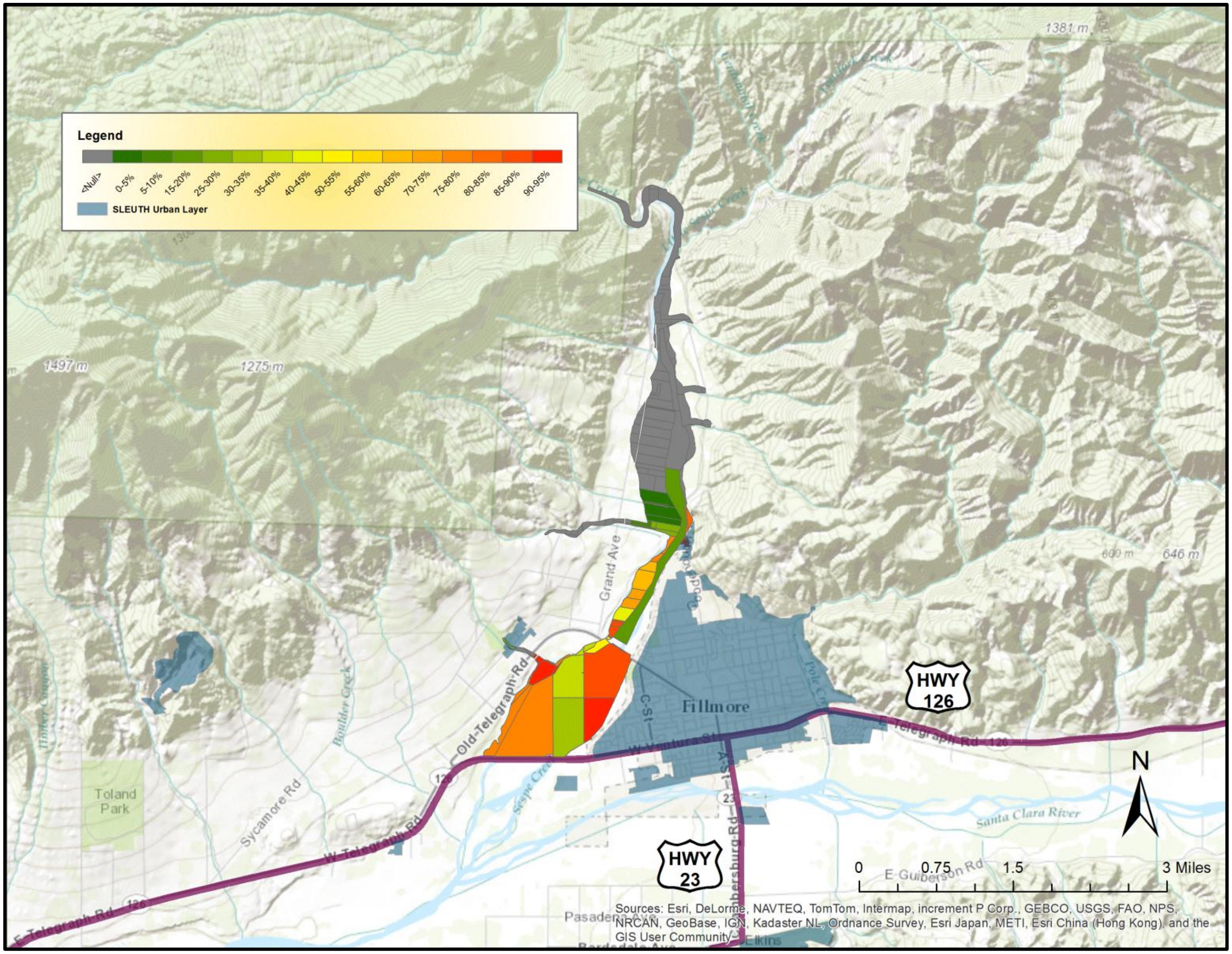

Figure 7.17: Region of interest parcels along Sespe Creek and their associated probability of being developed by 2063 according to the SLEUTH model

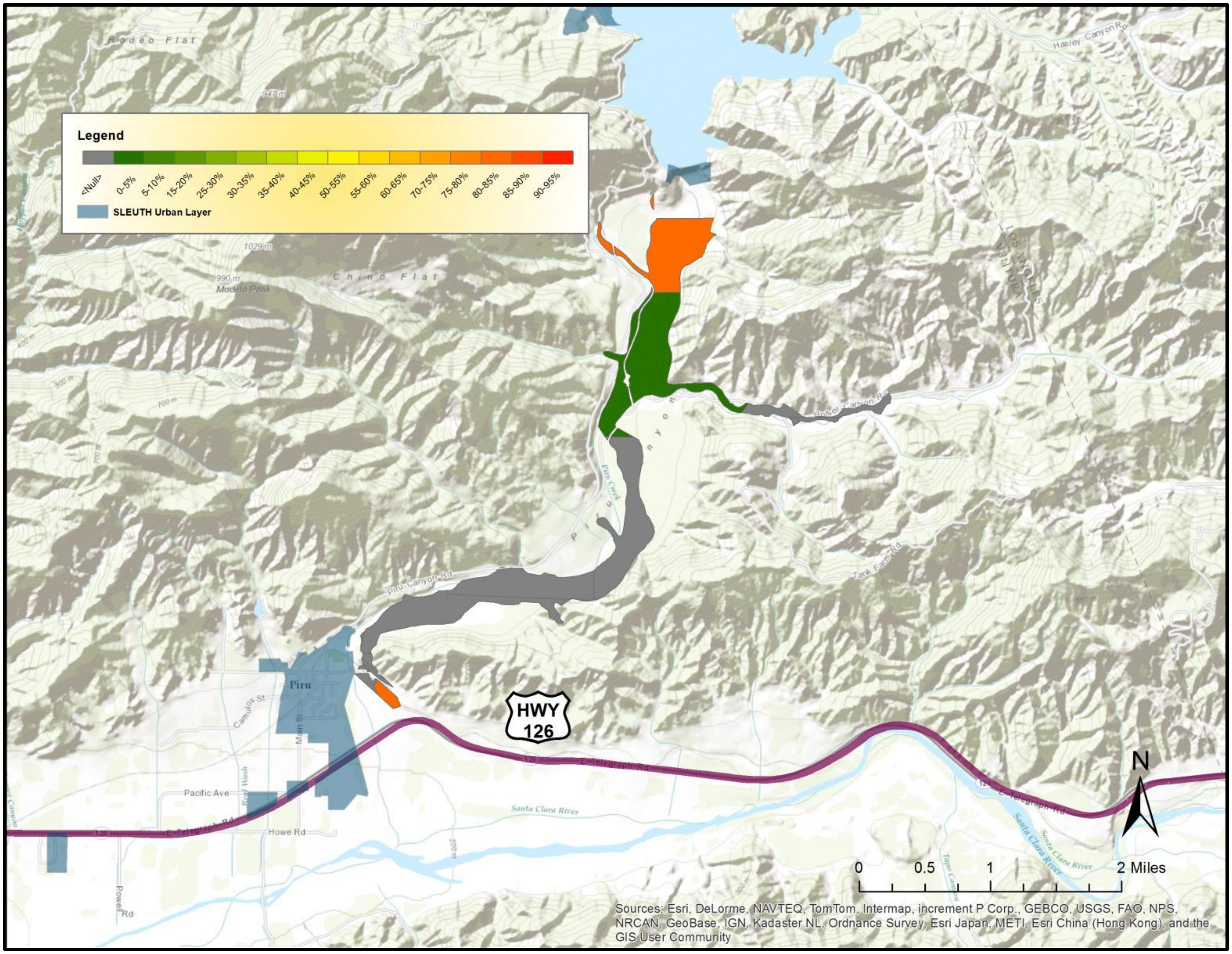

Figure 7.18: Region of interest parcels along Piru Creek and their associated probability of being developed by 2063 according to the SLEUTH model

7.3 Hydrology Analysis- Benefit to Downstream Flood Reduction

Using velocity vector and flood height data from the MIKEFLOOD module for a 100-year flood event along the Santa Clara River, 98 parcels adjacent to the river's mainstem were identified as potentially providing downstream flood benefits if conserved (See Figure 7.19). Parcel selection was made by examining directional magnitude vectors with average parcel flood velocities and volumes. Flood data was only available for parcels along the mainstem of the Santa Clara River, thus hydrological analysis was not conducted for the river's tributaries. Selected parcels can be ranked using average parcel volumes (acre-feet) calculated from the results of the MIKEFLOOD models.

Of the 485 parcels in the ROI, 98 parcels were selected representing approximately 44 percent of the floodplain (i.e. 2,350 acres of the total 5,422 acres). Only 20 percent of the parcels in the ROI were selected. This shows that on average, parcels selected in the hydrological analysis had large areas relative to other parcels in the ROI that were not selected. Individual parcel volumes ranged from 0.47 acre-feet to 444.77 acre-feet with an average parcel volume of 83.1 acre-feet (Figure 7.20). Highest ranked parcels were found in wider areas of the 500-year floodplain with the largest land surfaces and flood heights. The top ten ranked parcels were found throughout the floodplain, with no identifiable trend. Figures 7.21-7.23 show average flood volumes in all of the parcels selected in the hydrological analysis.

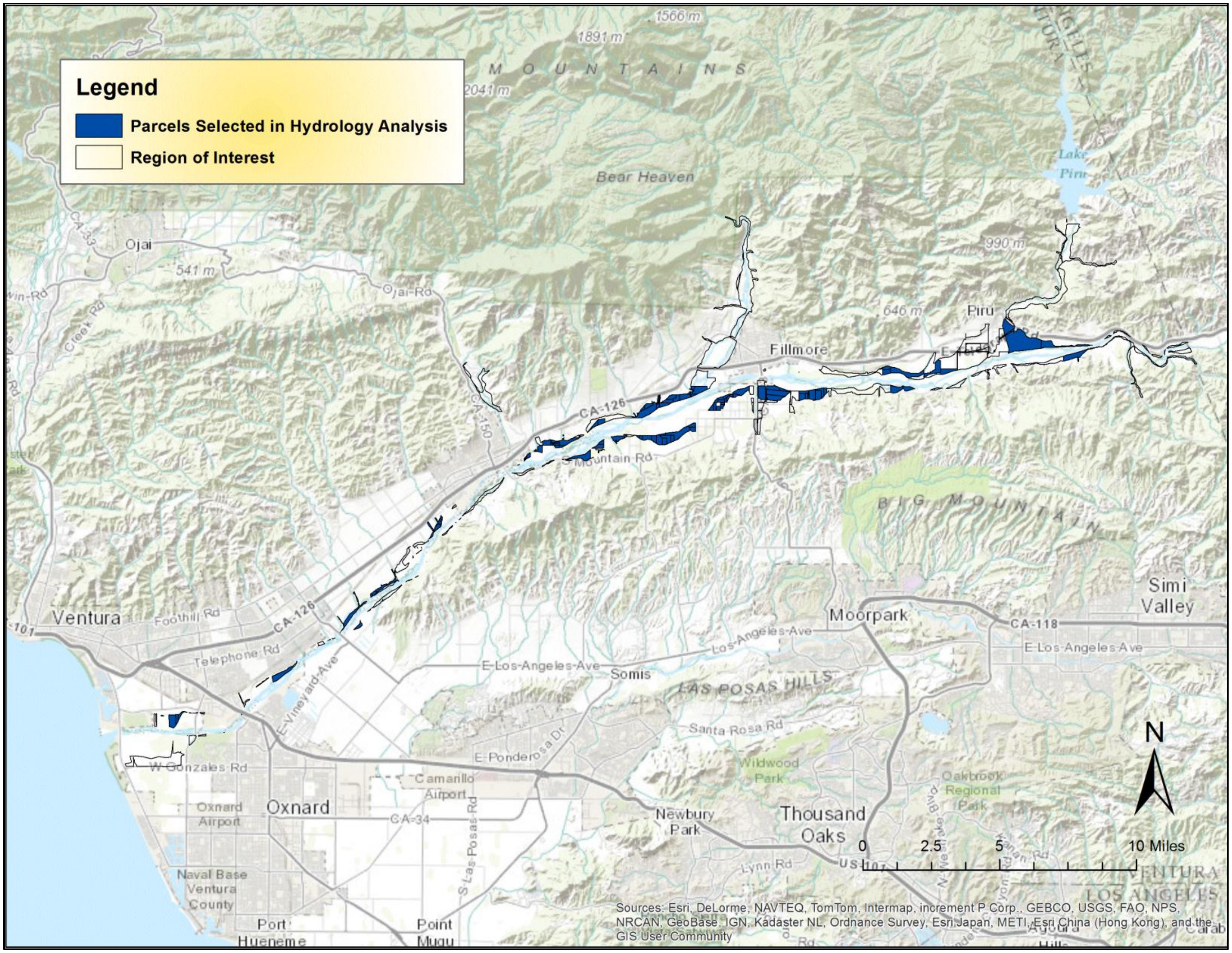

Figure 7.19: Parcels selected for potential benefit to downstream flood reduction.

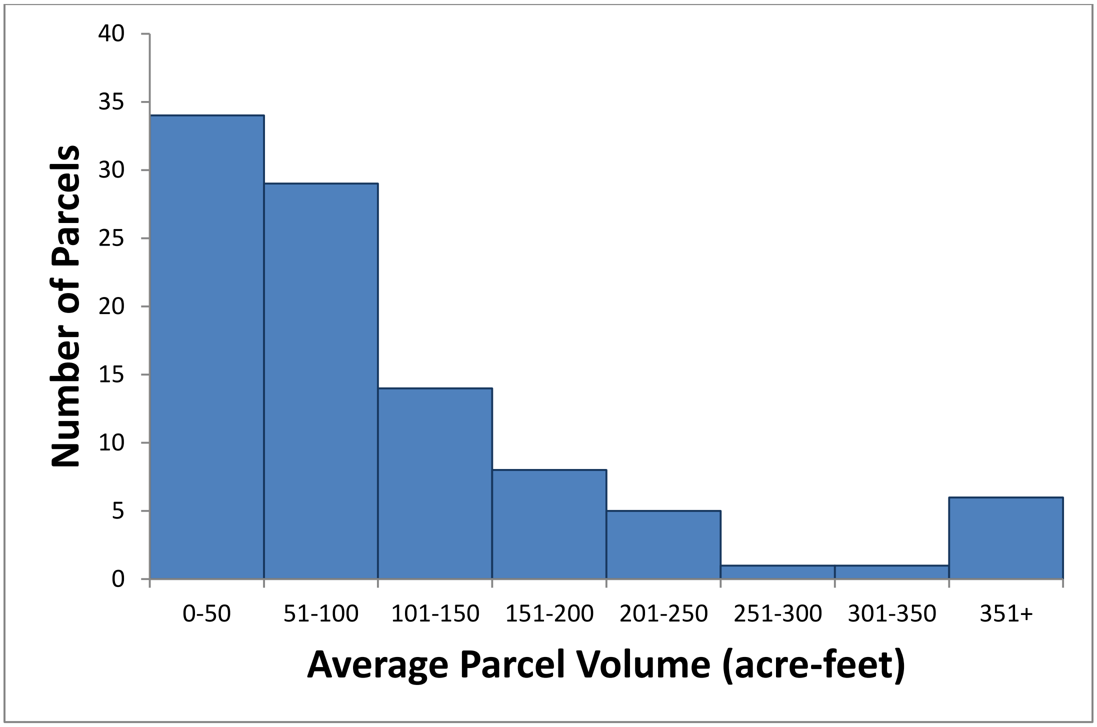

Figure 7.20: Frequency distribution of the number of parcels and average parcel volume (acre-feet) in the region of interest along the mainstem of the Santa Clara River

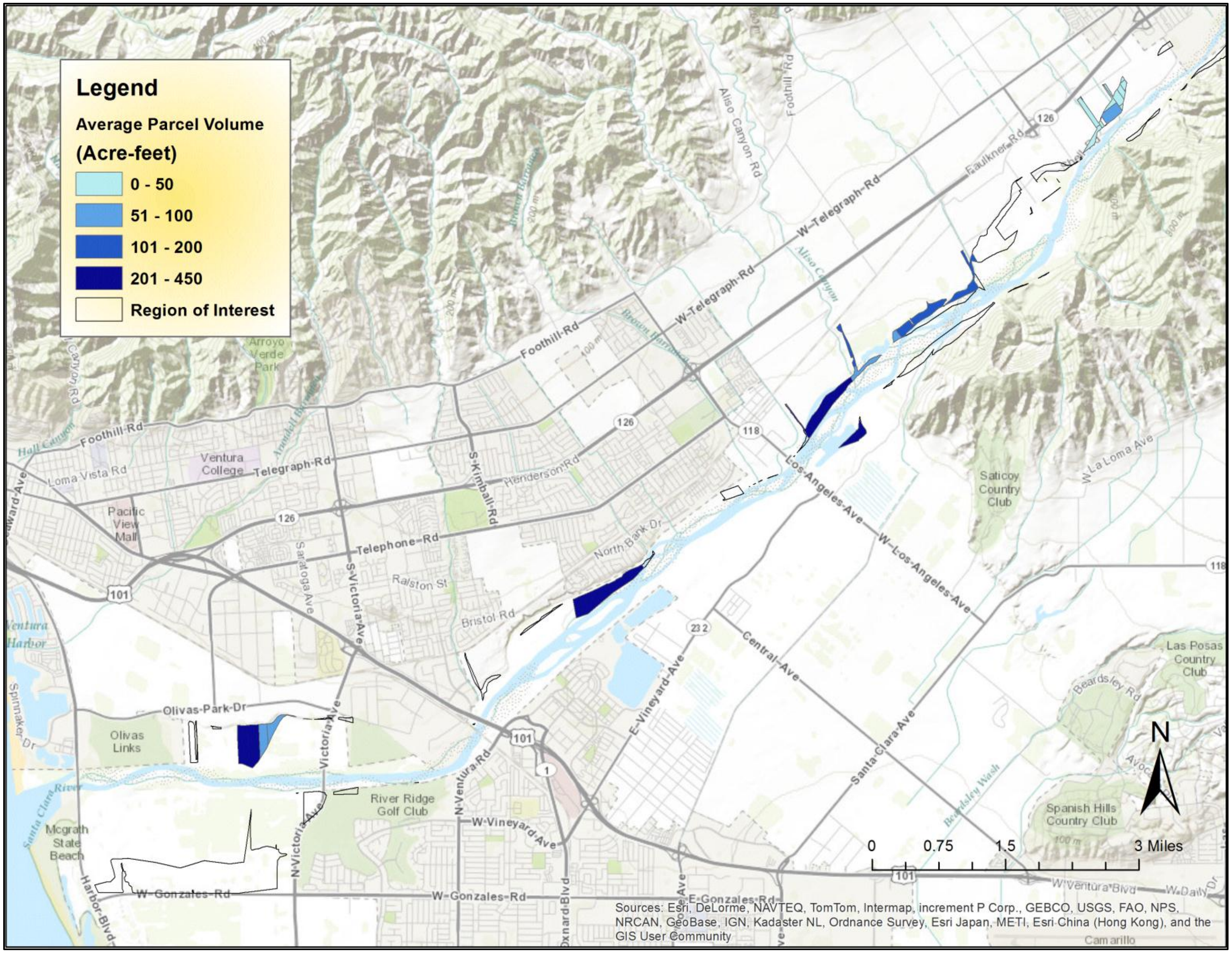

Figure 7.21: Average Flood Volumes (acre-feet) in Ventura Region of Santa Clara River mainstem

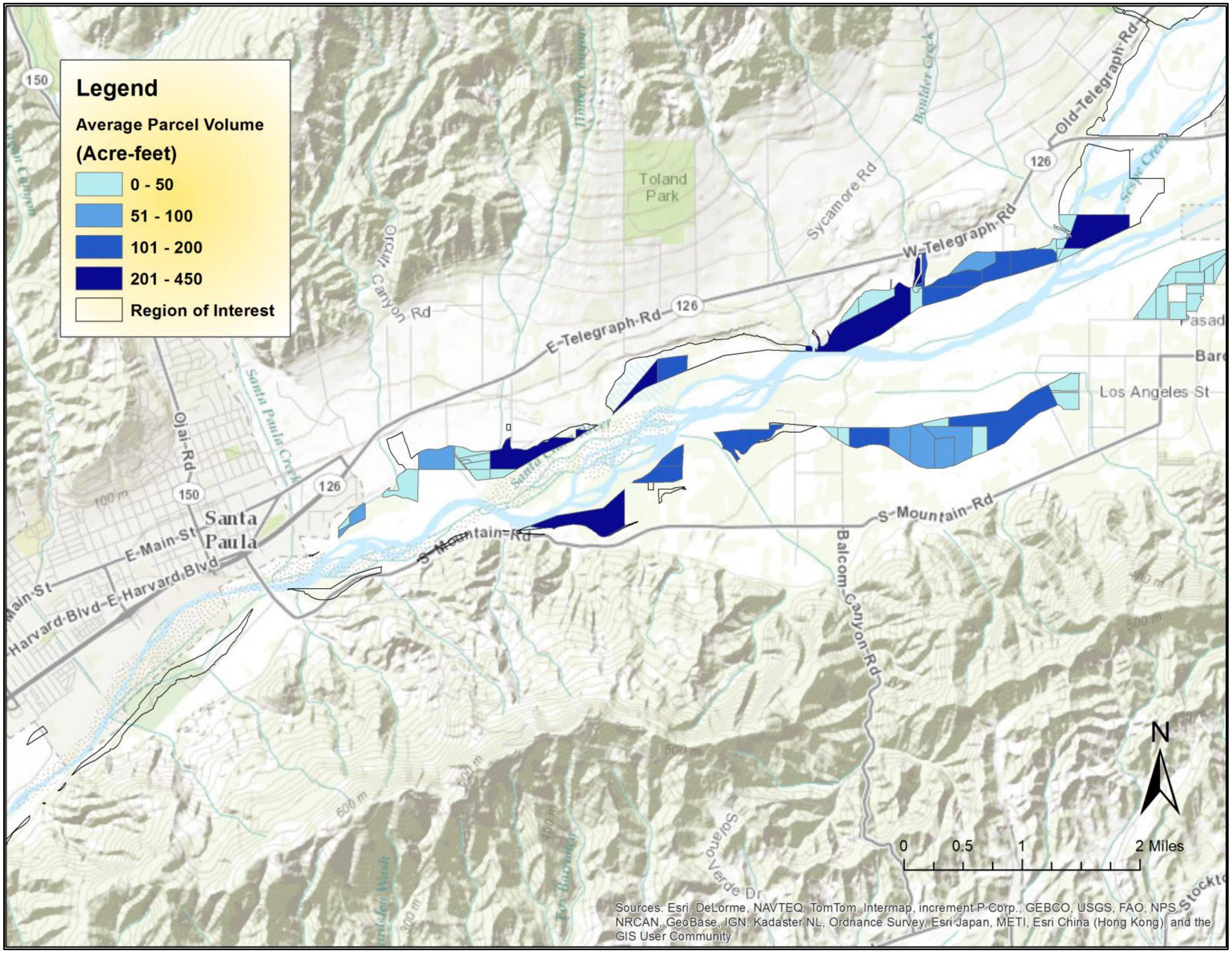

Figure 7.22: Average Flood Volumes (acre-feet) in Santa Paula Region of Santa Clara River mainstem

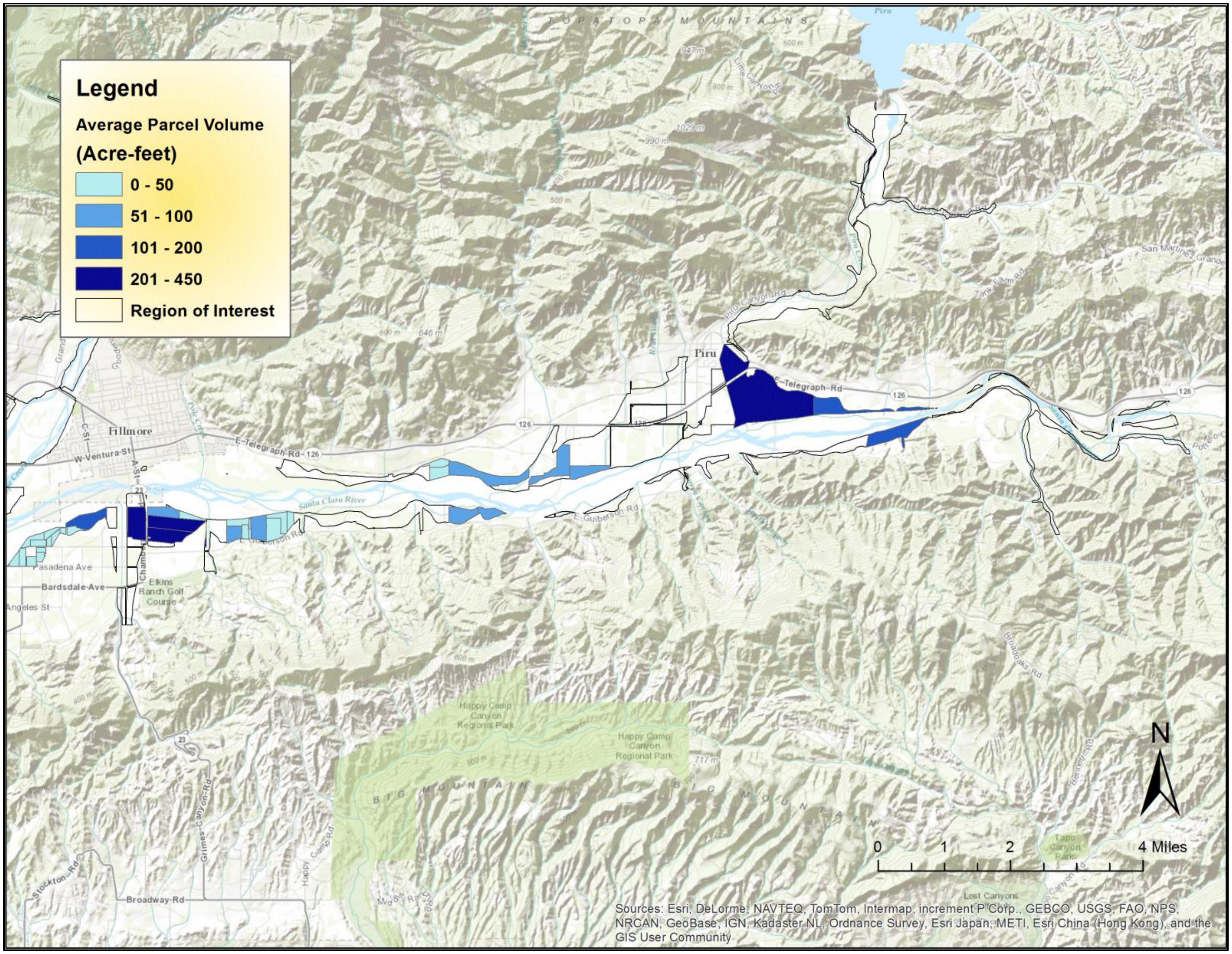

Figure 7.23: Average Flood Volumes (acre-feet) in Fillmore Region of Santa Clara River mainstem

7.4 Combining Weighted Overlay Analysis and Hydrology Analysis

The results of the WOA and hydrology analysis were combined to form tiers based on both of these factors (See Figure 7.24). Tier 1 represents the highest priority parcels; they include parcels with final WOA scores greater than the median score and those selected to provide potential benefits to downstream flood reduction. Tier 2 includes parcels with final WOA scores greater than the median but no hydrological benefits. Parcels in tier 3 have hydrological benefits, but final WOA scores less than the median. Lastly, tier 4 parcels have final WOA scores less than the median and no hydrological benefits.

Table 7.1 shows the number of parcels in each tier. Most of the parcels fall into tiers 2 and 4 because only a total of 98 parcels were selected to provide downstream flood reduction benefits. Details of all forty-four tier 1 parcels are displayed in table 7.2. Figures 7.25-7.26 display the tiers throughout the ROI.

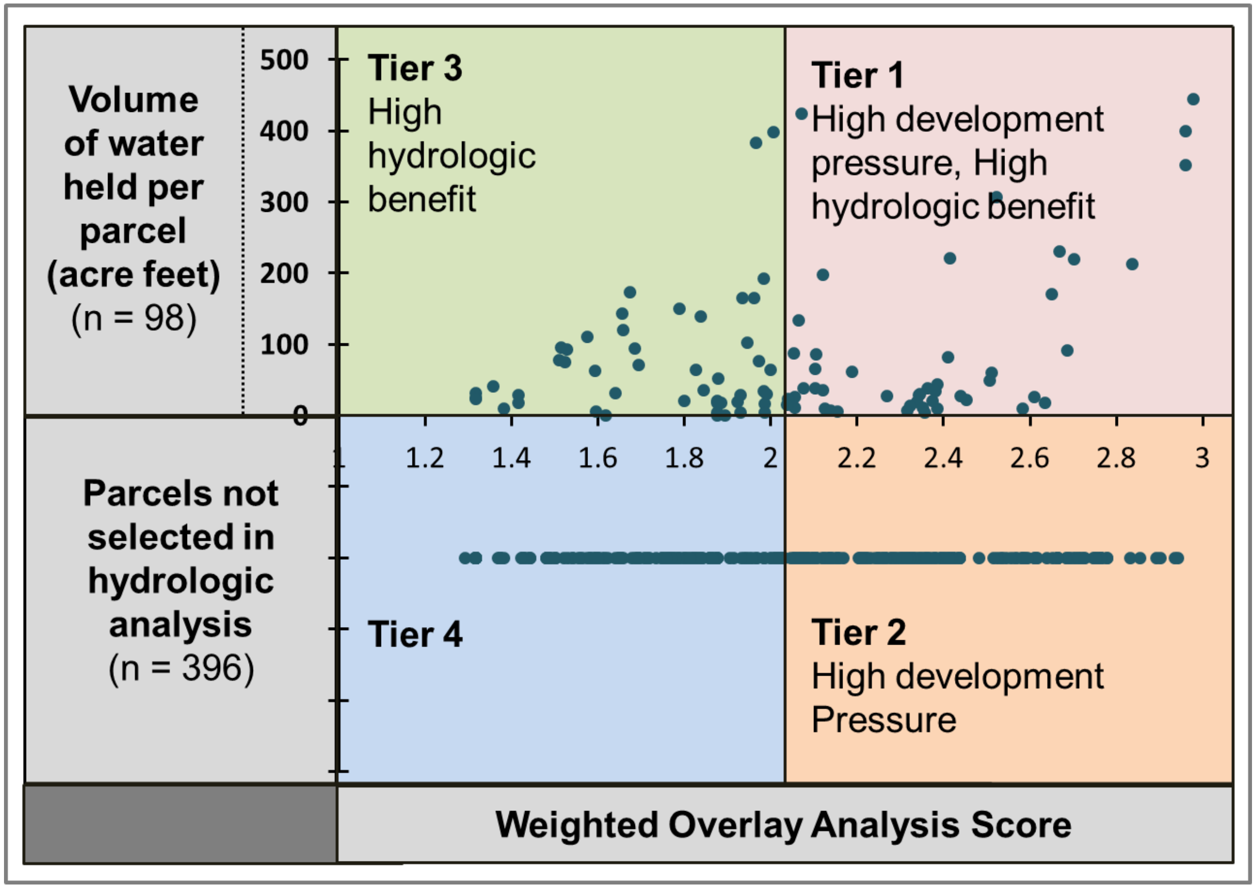

Figure 7.24: Tier Designation for Combination of WOA and Flood Reduction Results. Each point represents a parcel with its position on the x axis indicating its likelihood of development and its position on the y axis indicating the volume of flood water that parcel potentially attenuates during a 100 year flood.

Table 7.1: Statistics of Tiers of WOA and Hydrology Analysis

Tier	Number of Parcels	Average WOA Score	High Score	Low Score	Average Volume (acre-feet)	Average Acreage
1	44	2.40	2.98	2.06	98.70	28.04
2	199	2.41	3.29	2.06	-	8.85
3	52	1.77	2.05	1.32	70.54	21.13
4	190	1.69	2.06	1.29	-	7.00

Table 7.1: Tier 1 Parcels of WOA and Hydrology Analysis

Proprietary information, omitted from public report.

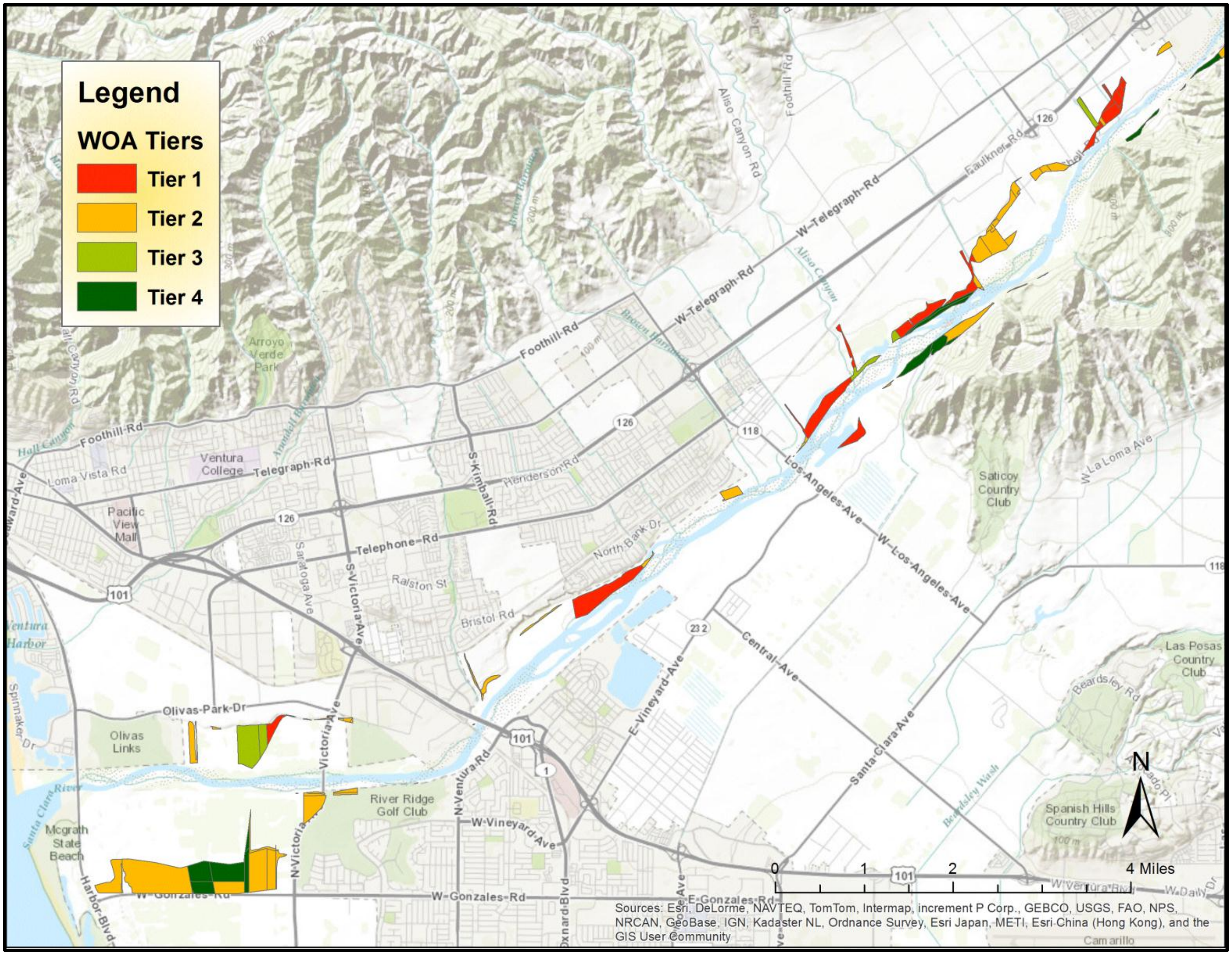

Figure 7.25: WOA tiers for Ventura Region of Santa Clara River mainstem

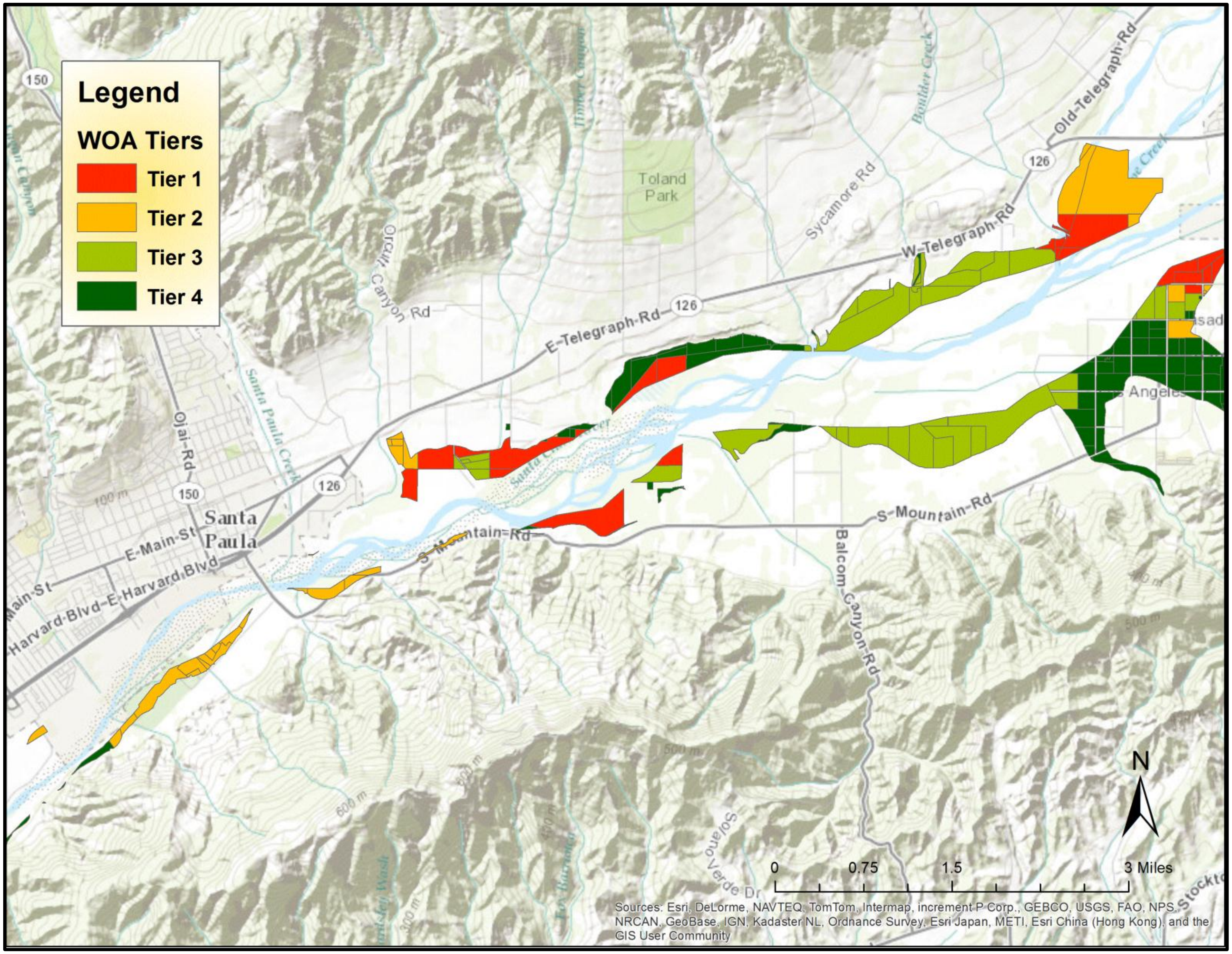

Figure 7.26: WOA tiers for Santa Paula Region of Santa Clara River mainstem

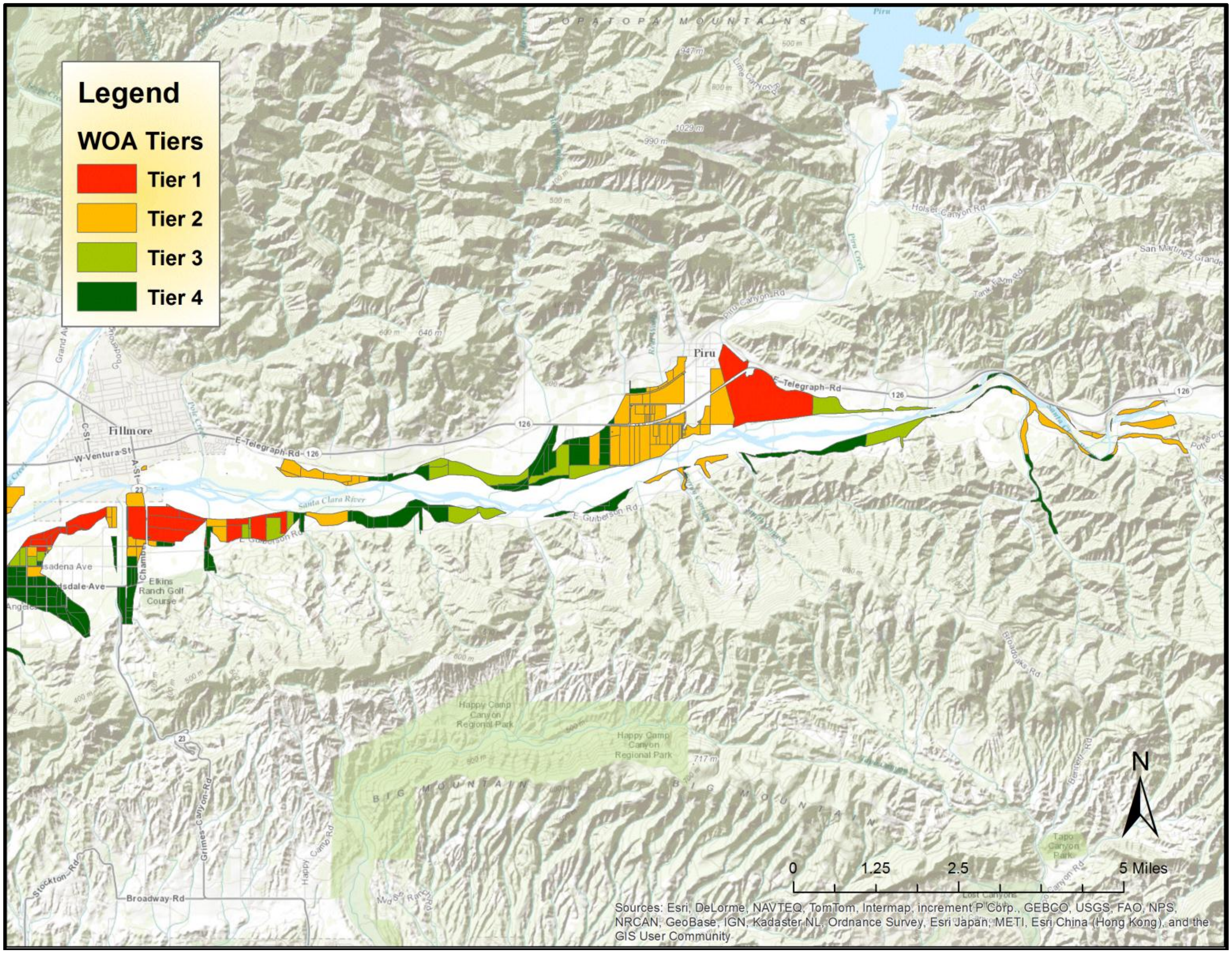

Figure 7.27: WOA tiers for Fillmore Region of Santa Clara River mainstem

7.5 Combining SLEUTH and Hydrology Analysis

Results from the SLEUTH model and the hydrology analysis were combined to create 4 priority tiers as was done with the combination of the WOA results and the hydrology analysis (See Figure 7.28). Tier 1 includes parcels with greater than 30 percent probability of development in 50 years and potential benefit to downstream flood reduction. Parcels in tier 2 have probabilities of development greater than 30 percent but low hydrological benefits. Tier 3 parcels have less than 30 percent probability of development and high hydrological benefits. Lastly, tier 4 has a probability of development less than 30 percent and low hydrological benefits.

Table 7.3 shows the number of parcels in each tier, the average development probability in each tier, average flood volume per tier, and average acreage. Because a majority of the parcels in the SLEUTH analysis were predicted to have less than 5% chance of development, tier 4 is the largest tier with over 200 parcels. Table 7.4 provides relevant data on tier 1 parcels.

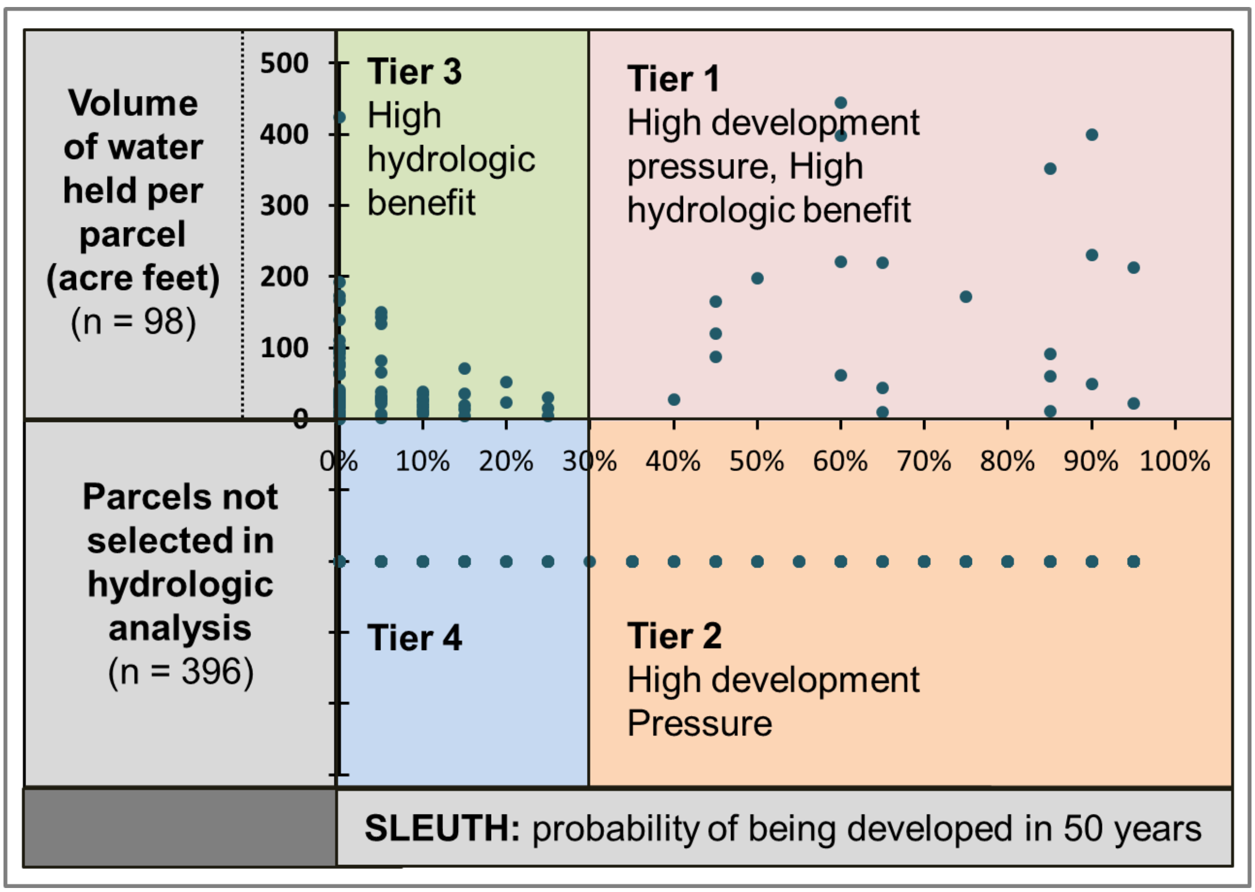

Figure 7.28: Tier Designation for SLEUTH and Flood Reduction Results

Table 7.3: Statistics for Tiers of SLEUTH and Hydrology Analysis

Tier	Number of Parcels	Average Development Probability	Average Volume (acre-feet)	Average Acreage
1	16	55-60%	125.49	28.90
2	95	65-70%	-	6.03
3	65	0-5%	85.14	25.54
4	217	0-5%	-	9.71

Table 7.4: Tier 1 Parcels, SLEUTH and Hydrology Analysis

Proprietary information, omitted from public report.

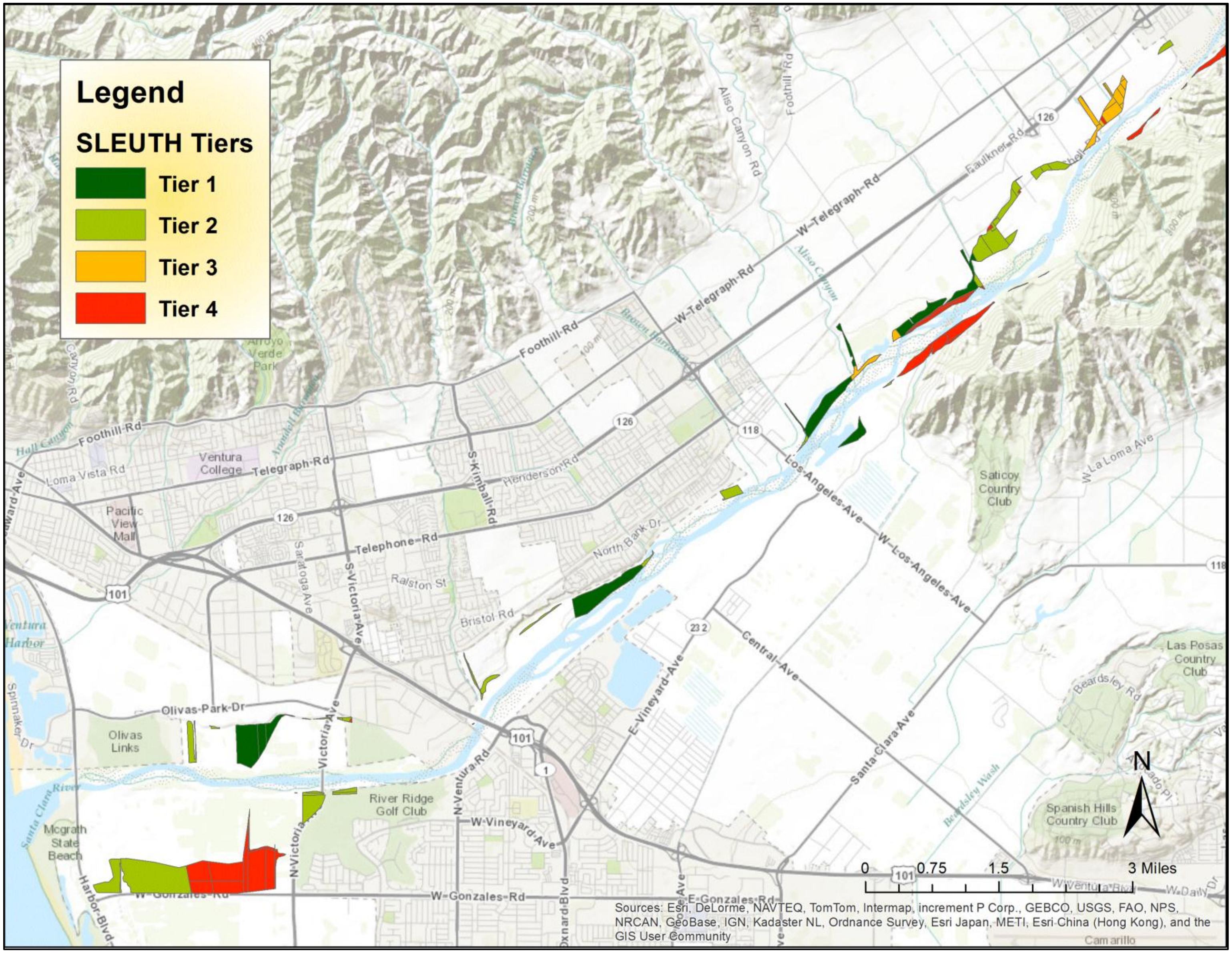

Figure 7.29: SLEUTH tiers for Ventura Region of Santa Clara River mainstem

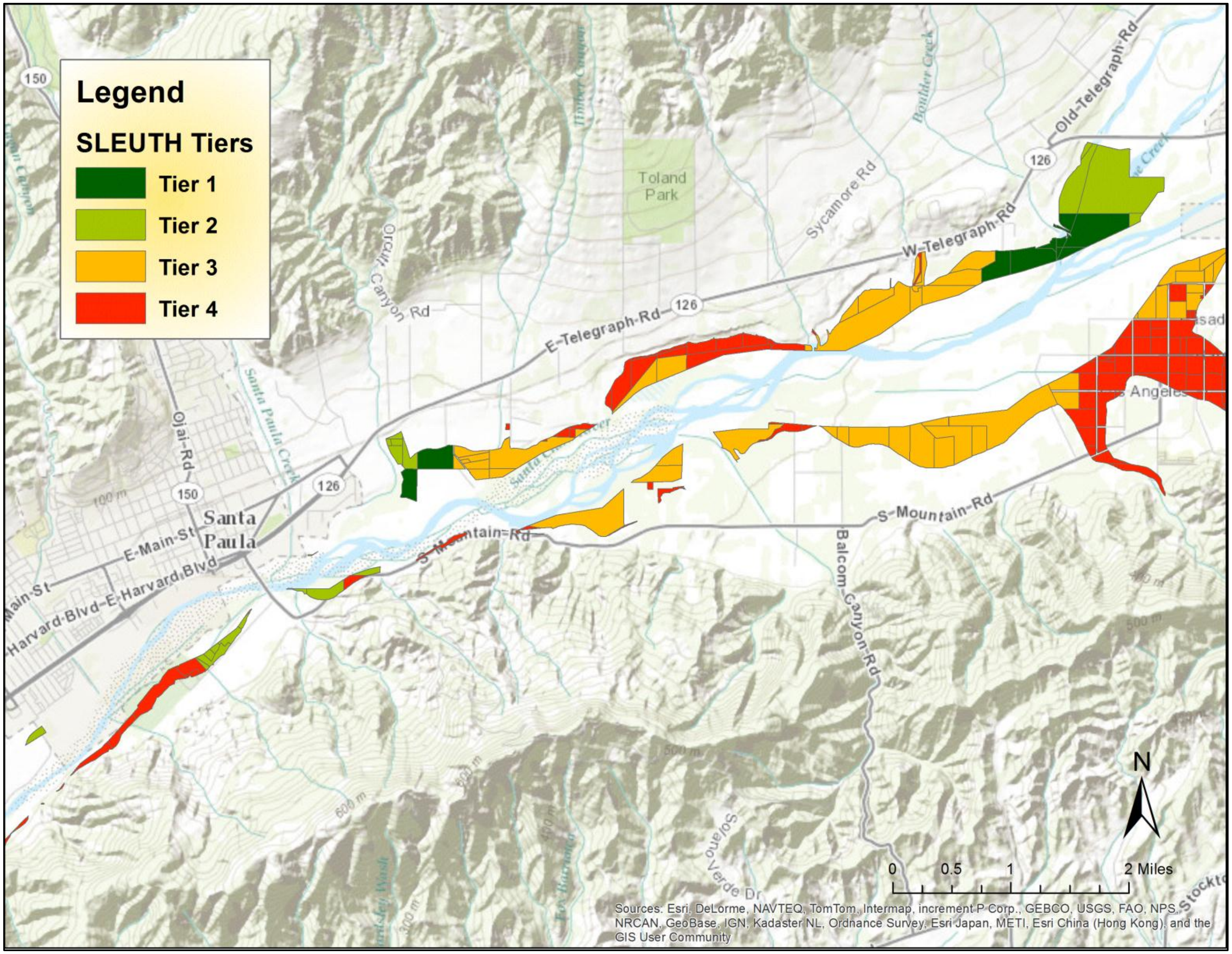

Figure 7.30: SLEUTH tiers for Santa Paula Region of Santa Clara River mainstem

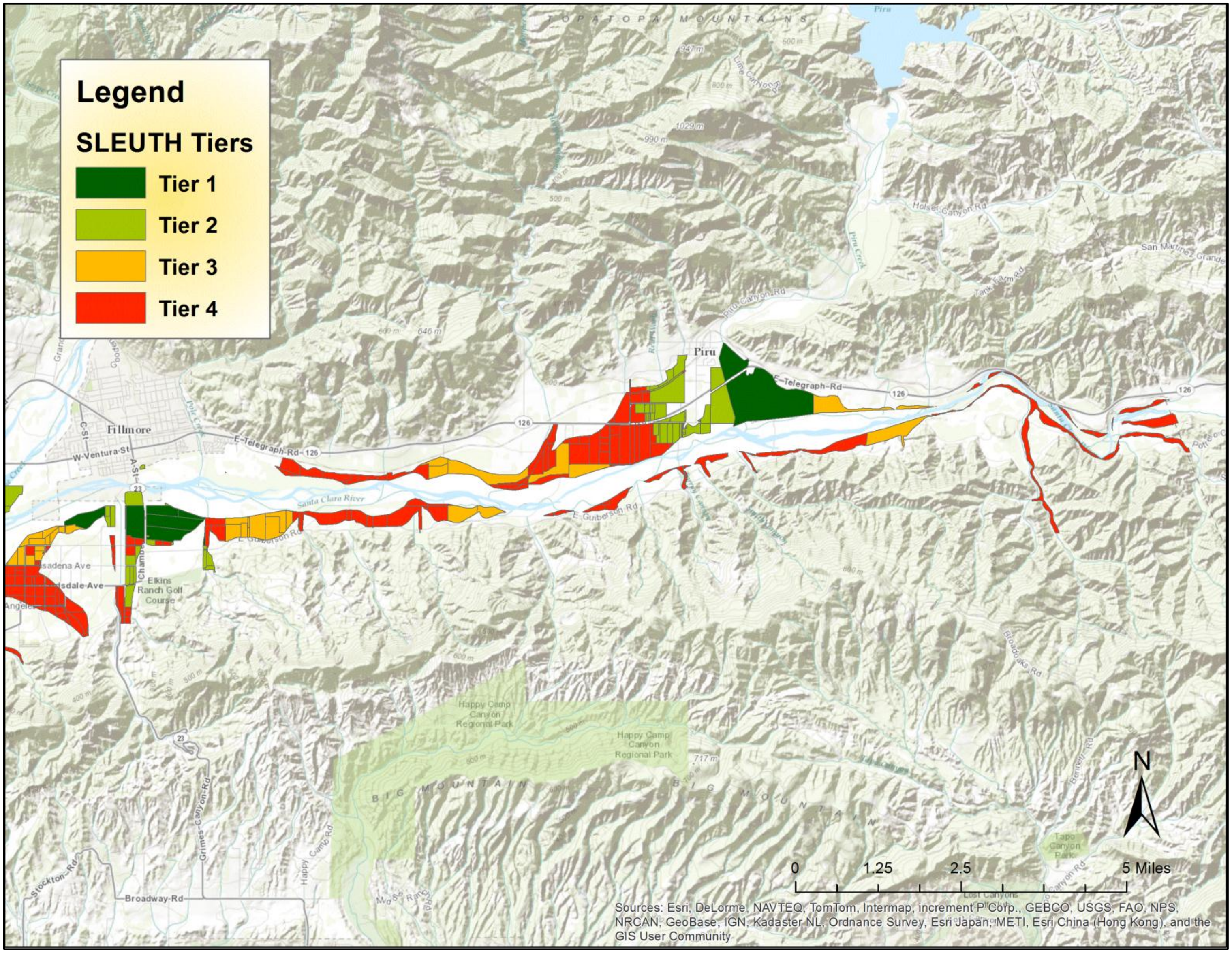

Figure 7.31: SLEUTH tiers for Fillmore Region of Santa Clara River mainstem

7.6 Top Priority Parcels

The parcels that fell into tier 1 for both of the development models were selected to be the top priority parcels. A total of 18 parcels were selected; this group will hereafter be referred to as the "top priority parcels" (See Table 7.5). These parcels were found to have flood attenuation benefit, had WOA scores greater than the median score and had probabilities greater than 30 percent in the SLEUTH model. The top priority parcels are displayed in Figure 7.32. Figure 7.33 shows the clustering of top priority parcels located to the south of Fillmore.

Table 7.5: Top Priority Parcels (Parcels in Tier 1 of both WOA and SLEUTH combinations with Hydrology Analysis)

Proprietary information, omitted from public report.

Proprietary information, omitted from public report.

Figure 7.32: Top Priority Parcels along the Santa Clara River mainstem

Proprietary information, omitted from public report.

Figure 7.33: Top Priority Parcels in Fillmore of the Santa Clara River mainstem

7.7 Easement Valuation

Proprietary information, omitted from public report.

7. 8 Decision Guidance Tool

Detailed results for each model used in our prioritization analysis were provided to TNC in a comprehensive georeferenced database on a per parcel basis. Additional information was provided in the database as an effort to assist TNC in easement acquisition and highlight parcel characteristics relevant to TNC's overall conservation goals. This database was developed recognizing that not all factors could be incorporated in the prioritization model, and that other factors may be important when considering what parcels should be acquired both now and in the future. A summary of the data collected for this database is provided below.

Agricultural Considerations

Crop Type

Table 7.6 shows crop type per parcel in the ROI as identified through the assessor's role site use codes. Site use codes were transcribed and added to the decision database.

Table 7.6: Number of Parcels in ROI for each Agricultural Site Use Code

Site Use	Number of Parcels
Truck Crops	98
Orchards (Mixed)	140
Avocados	46
Oranges	148
Lemons	53
Mixed	42
Pasture/Rangeland	76
Nursery Crop and Seeds	30
Field and Seed Crops	3
Grapefruits	2
Deciduous	1
Livestock	1
Greenhouses	3
Field Flowers	1
Miscellaneous	1
Agriculture Related Activities	1

Farmland Monitoring & Mapping Program Designations

Through the State of California's Department of Conservation's Farmland Monitoring &

Mapping Program agricultural lands are rated, farmland designations, based upon land use, irrigation, and soil quality. Farmland designations include: Prime Farmland, Farmland of Statewide Importance, Unique Farmland, and Farmland of Local Importance are identified on a per parcel basis (See Table 7.7).

Table 7.7: FMMP Designations in ROI

FMMP Designation	Number of Parcels
Prime Farmland	400
Farmland of Statewide Importance	44
Unique Farmland	31
Farmland of Local Importance	8

Ecological Characteristics/Considerations

Conservation Priorities

The 2008 Conservation Plan for the Lower Santa Clara River Watershed and Surrounding Areas established conservation targets for TNC that has led to prioritizing tracts along the river for conservation. These targets included: coastal communities, riparian forest and scrub communities, grasslands, coastal scrub communities, oak woodlands, chaparral communities, aquatic vertebrates, and wide ranging terrestrial vertebrates. Based upon these targets as well as size, ownership, habitat characteristics, connectivity to protected areas and wildlife linkages, and environmental threats, parcels in the lower Santa Clara River Watershed were tiered. Tier 1 represented parcels with the highest priority while tier 3 represented parcels with the lowest priority. Data on these tiers have been included.

Wildlife Linkages

South Coast Wildlands' South Coast Missing Linkages project has identified important habitat corridors between the fragmented natural areas in Southern California. TNC in their Lower Santa Clara River Watershed and Surrounding Areas Conservation Plan identified protecting these linkages as a conservation target. Within the database, parcels that are within these linkages are identified (See Figure 7.34). Two linkages were found to overlap with parcels in the ROI: the Santa Monica- Sierra Madre linkage and the Sierra Madre- Castaic linkage (See Table 7.8).

Table 7.8: Wildlife Linkages in ROI

Linkage	Number of Parcels
Santa Monica- Sierra Madre	236
Sierra Madre- Castaic	3

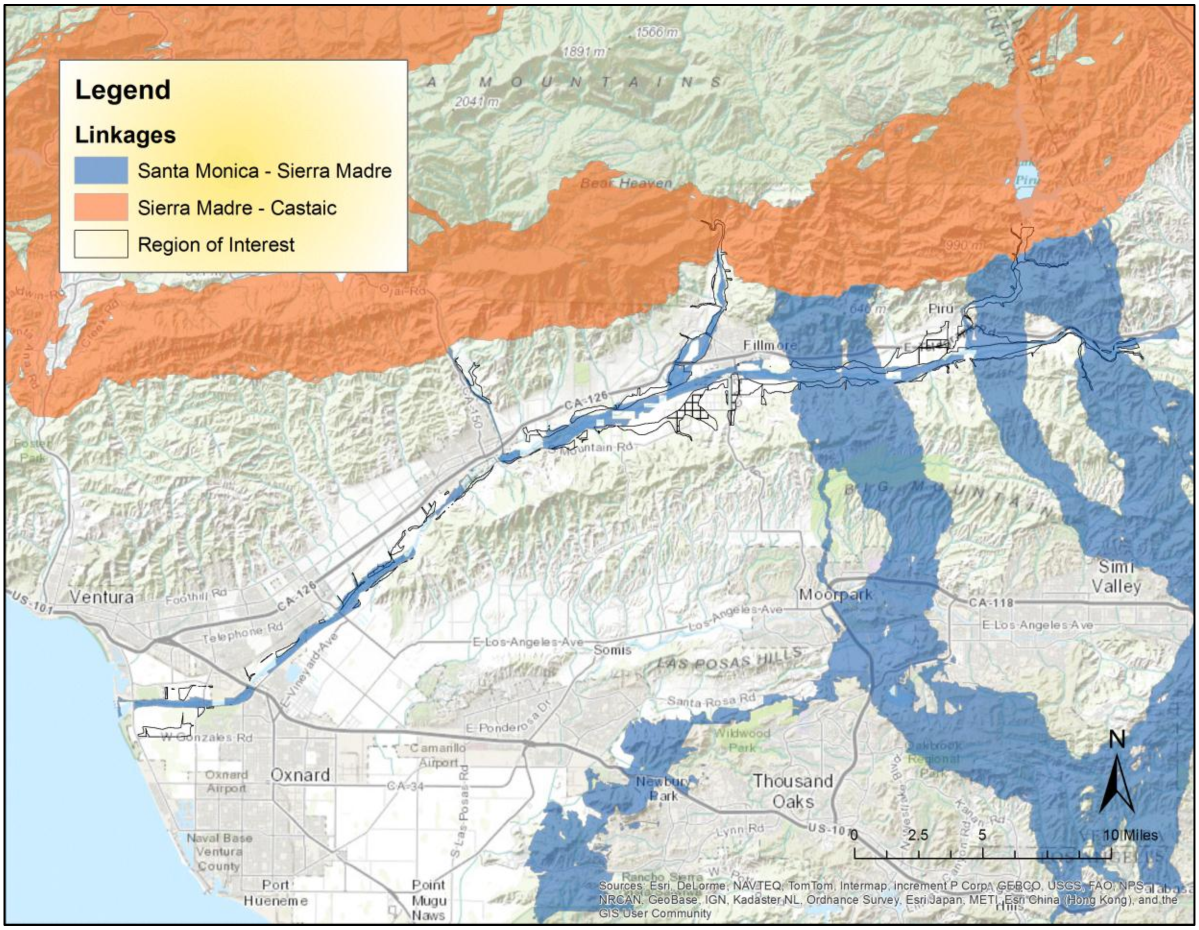

Figure 7.34: Wildlife Linkages as Identified by the SC Wildland's Missing Linkages Project

Rare, Threatened, and Endangered Species Habitat
Though the Santa Clara Watershed is home to numerous rare, threatened, and endangered species, there is only minimal established habitat. Currently, most of the water ways within the lower watershed are listed as critical habitat for the Southern Steelhead (See Figure 7.35). Also, riparian habitat north of Piru is listed habitat for the Least Bell's Vireo.

Data on past and present rare, threatened, and endangered species as well as federal and state species listed species is provided. Per parcel information includes species common names, presence (present, extirpated, etc.), and federal and state listing.

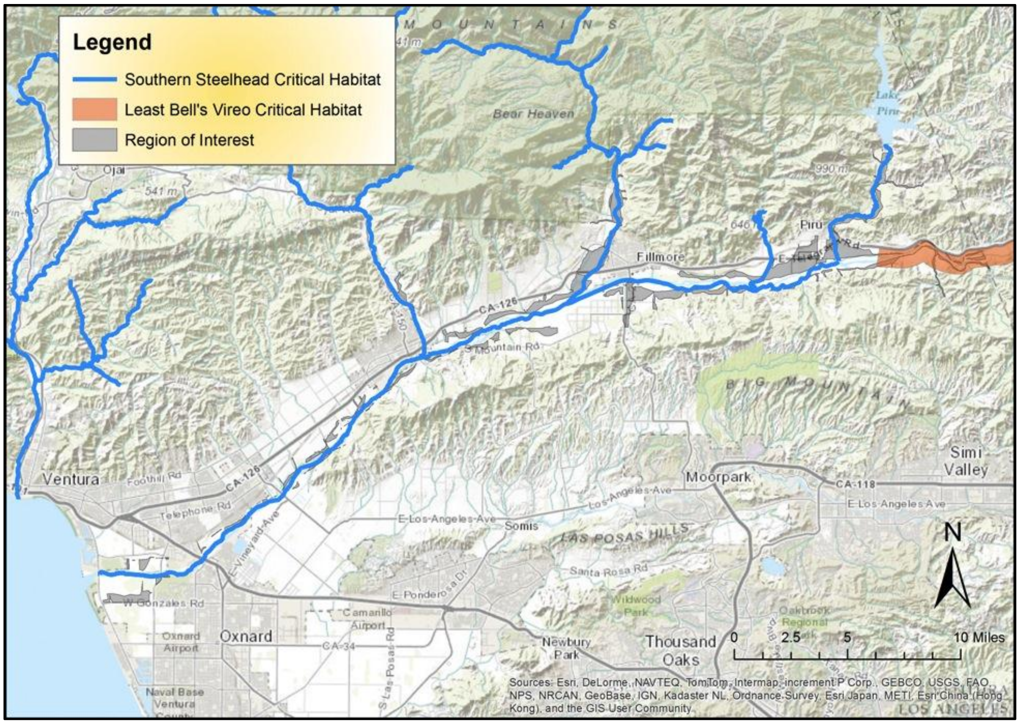

Figure 7.35: Designated Critical Habitat for Federally Listed Endangered Species

Invasive Species Density

Arrundo donax, one of the most problematic invasive plant species in coastal riparian areas in southern California and has already invaded much of the riparian habitat of the lower Santa Clara River. Data obtained from the California Invasive Plant Species Council on Arrundo donax percent cover is included in the database. Each parcel is assigned a percent cover of Arrundo donax (See Table 7.9 & Figure 7.36 for example of data).

Table 7.9: *Arrundo donax* percent cover in ROI

Percent Cover of *Arrundo donax*	Number of Parcels
1-5%	96
6-10%	10
11-25%	7
26-50%	14
51-75%	15
76-100%	3

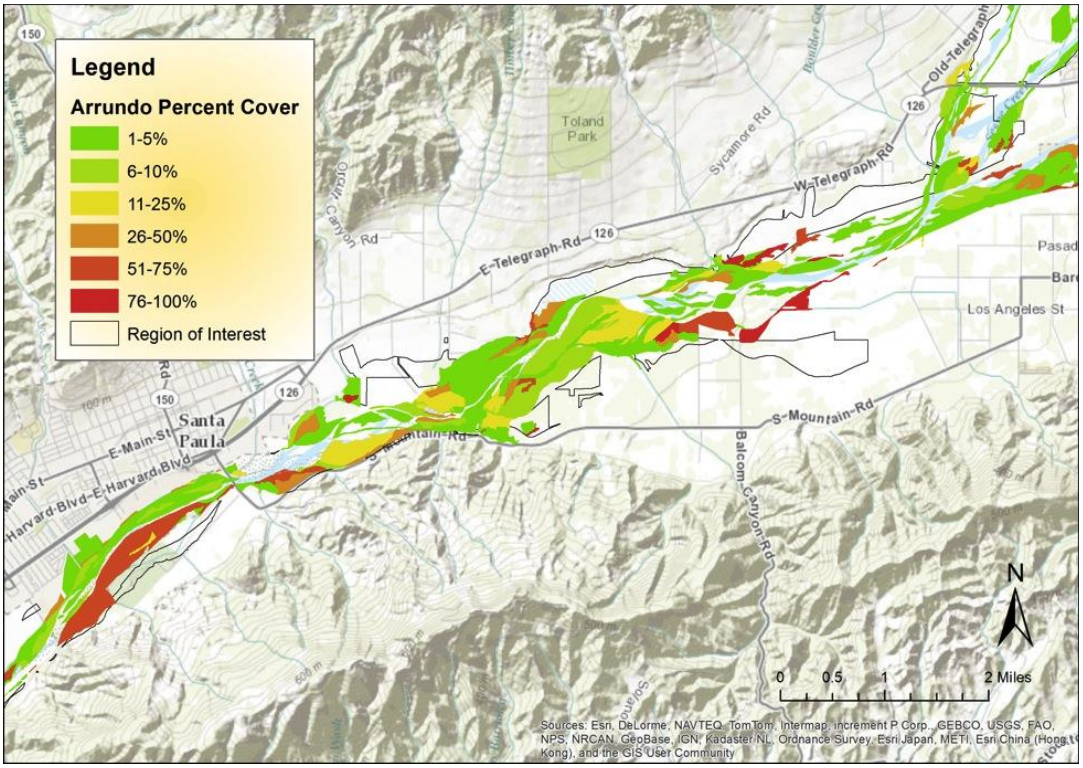

Figure 7.36: Percentage of Arrundo Cover for Santa Paula Region

Adjacency to Existing Protected Properties
TNC and Friends of the Santa Clara both have fee title purchases within the ROI for conservation purposes. 18 parcels adjacent to these protected properties have been identified. These parcels are identified in the database.

Additional Parcel Characteristics/Considerations

Land Conservation Act Status and Contract Expiration Date
In 1965 California passed the Land Conservation Act, also known as the Williamson act, to help preserve the state's agricultural and open space lands. Currently, 113 parcels in the ROI are taking advantage of this program, which secures tax benefits for land owners who agree to keep their property in agricultural or open space use (See Figure 7.37). These parcels account for over 12,000 acres of farmland along the Santa Clara River.

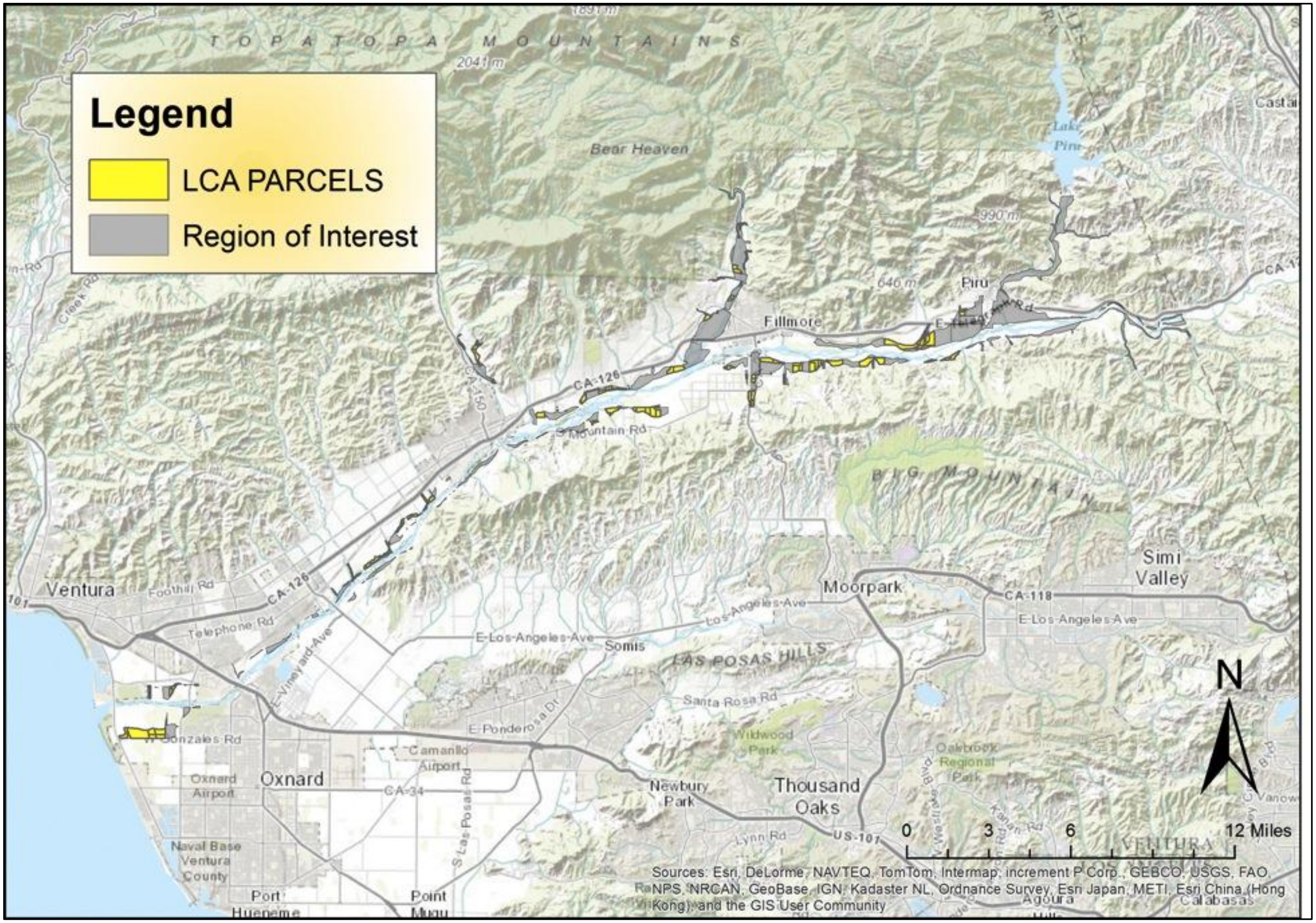

Figure 7.37: Land Conservation Act Contracted Parcels

Factors from Prioritization

In addition to the inclusion of these additional factors, the decision guidance database also includes specifics on the factors that were included in the prioritization model.

8. Discussion

8.1 Weighted Overlay Analysis Model

Weighted Overlay Analysis Results

The top weighted input factors (i.e. zoning/land use designation, proximity to urban growth boundaries, size of parcel, and floodplain delineation) influenced model results most significantly. Proximity to local roads, major roads, and levee tie in had negligible impacts on model results because of small input factor weights. In general, parcels around urban growth boundaries received the highest parcel scores and ranked highest in the Weighted Overlay Analysis (WOA) results. As distance from urban growth boundaries increased, parcel scores decreased. This trend suggests that parcels closest to urban growth boundaries have the highest development pressures and are most likely to become developed in the future. This trend occurred along the mainstem of the river as well as its tributaries.

Strengths and Weaknesses of the WOA Model

The results of the WOA ranked agricultural and open space parcels for likelihood of future development. The strengths of this model are its use of local expert knowledge and its ability to identify development pressure based on quantifiable input factors. There are, however, several weaknesses inherent in the WOA model that, in some cases, could be improved upon in future applications. These weaknesses are discussed in detail below.

The WOA identified parcels with the highest development pressure using seven input factors. The assumption was made that the input factors used in the model were the primary factors influencing parcel development in the future. These factors were developed with input from The Nature Conservancy (TNC), the Ventura County Watershed Protection District (VCWPD), Ventura County Planners, Ventura County LAFCo, and faculty at The University of California, Santa Barbara. It is important to note, however, that although WOA inputs were developed with expert opinion, they do not include socioeconomic factors such as willing sellers, agricultural land values, agricultural conservation easement costs, and transaction costs. This is primarily because these factors are subject to market conditions and are hard to capture accurately in a model. Market conditions were therefore, not included because their inherent variability could weaken spatial results. The assumption was also made that all areas in Ventura County were equally likely to become developed. This infers that all parcels outside of urban growth boundaries in Piru, Fillmore, Santa Paula, Saticoy, and Ventura had the same development pressure. This is highly unlikely because urban areas experience development pressure based on a variety of social factors that can differ widely between cities. Incorporating accurate economic and social development components into the model would strengthen the results and allow for easement purchase optimization by accounting for regional social development variability.

The weights used for each input factor in the WOA model have a large effect on the model results. Although these weights were derived with input from expert opinion, they still include a certain degree of subjectivity. Pairwise comparisons were not conducted with the advisory group; instead a ranked list of factors and anecdotal statements were used to develop the comparison scoring later. In the future, incorporating historical data and/or input from a larger group of professional planners who are involved throughout the entire process could strengthen the development of weights.

Another caveat of the WOA model involves the distance-dependent ordinal ranking system that was used within many of the input factors. An example of this is the proximity to urban growth boundaries input factor. The distances that comprise a score of 1-4 were chosen somewhat subjectively, but were drawn from relevant distances within our study area such as the length of a street block and were developed to partition the ROI to prevent large areas from being outside of score ranges. Other sources used to develop these distances included relevant scientific literature, and consultations with the advisory group.

A further limitation of the WOA model is that each model input factor was developed using an ordinal ranking system, meaning that a score of 4 is always better than a 3, 2, or 1. Under this methodology, scores cannot be compared statistically, which limits the analysis that can be conducted with the results. The use of a model with nominal scores would avoid this problem for future analysis.

8.2 SLEUTH Discussion

SLEUTH Trends

The SLEUTH prediction model was run with three growth scenarios governed by three different exclusion layers. The primary urban growth prediction scenario is based on an exclusion layer that contains values that approximate the development restrictions of each zoning designation within the County. The second scenario provides an extreme development scenario in which no land use or regulatory restrictions are in place. This was achieved with a zero percent exclusion layer. The 75 percent SOAR boundary scenario provides a conservative development prediction for which areas outside of the current SOAR boundaries have 75 percent more resistance to becoming new growth. This scenario approximates what may occur if the urban growth boundaries under the SOAR initiative are maintained for the next 50 years. The results from the zoning-based primary urban growth scenario will be the main focus of the discussion section; the second and third scenario will also be discussed to provide the full range of potential results.

Due to the limited area of the ROI, certain SLEUTH data input elements are more influential than others. Because the ROI is a floodplain and slopes are generally mild, almost no areas are excluded as a result of the Slope layer; however, coefficients that utilize this layer do play a roll in preventing additional growth. The Hillshade layer consists of a DEM that gives the urban area spatial context, but does not contribute quantitatively to the SLEUTH analysis. This leaves the Exclusion, Urban and Transportation layers that primarily work to differentiate parcels within each ROI. The SLEUTH analysis was largely dominated by edge growth originating from existing urban areas. Evidence of this can be seen in the high best fit spread coefficient value of 99 that resulted from the model calibration and is also evident in the sustained high values during the model period of high growth (Table 8.1). This indicates that edge growth was a large factor in past urban growth (For additional information on the interaction of SLEUTH coefficients and their influence on growth see Appendix X). The best fit breed coefficient is relatively high as well (65); however, new spreading centers are not evident within the ROI.

The results from the SLEUTH model for both the mainstem and tributaries produced a bi-modal distribution of development probability predictions (Figure X.X and X.X[historgram in results section]), i.e. there were numerous parcels that were almost never selected and many parcels that were selected a large number of times across the 100 monte carlo simulations. The low selection cells become low urban development probabilities and the highly selected become the high probabilities.

Zoning Exclusion Scenario

Table 8.1 shows the five coefficients as they start from the best fit values gleaned from the final calibration and change over the 50 year time horizon as the model runs the Monte Carlo simulations. Figure 8.2—8.5 show the SLEUTH model output images beginning with the first year time step, 2003 (this is set in the past because some of the input data is from 2002), and the final time horizon, 2063. At approximately model year 2025, the dispersion, spread, and breed coefficients decline to values near or less than one and the slope resistance dramatically increases (Figure 8.1 graph). This dramatic decline in three of the growth coefficients and large increase in slope resistance reflects the model's response to a lack of developable land. The substantial increase in the slope resistance coefficient (Year 2025= 11.06, year 2063 = 99.97) reflects a decrease in flat developable land relative to steeper lands and increasingly steeper slopes are less likely to urbanize. The significant changes in growth coefficients around model year 2025 continue through the rest of the model run creating a leveling off of growth for the remainder of the model run (Figure 8.1). These factors and the lack of growth seen between 2025 and 2063 (Figure X.X and X.X) imply that the study area is built out by this date due to a lack of suitable developable land.

Table 8.1. SLEUTH Growth Coefficients for the Zoning Exclusion Scenario Updated at each time step

Year	Diffusion	Spread	Breed	Slope Resistance	Road Gravity
2003	30.00	99.00	65.00	5.00	41.00
2004	30.30	99.99	65.65	3.17	41.18
2005	30.60	100.00	66.31	1.27	41.37
2006	30.91	100.00	66.97	1.00	41.57
2007	31.22	100.00	67.64	1.00	41.77
2008	31.53	100.00	68.32	1.00	41.98
2009	31.85	100.00	69.00	1.00	42.19
2010	32.16	100.00	69.69	1.00	42.40
2011	32.49	100.00	70.39	1.00	42.62
2012	32.81	100.00	71.09	1.00	42.84
2013	33.13	100.00	71.79	1.00	43.06
2014	33.42	100.00	72.41	1.00	43.25
2015	33.62	100.00	72.84	1.00	43.39
2016	33.70	100.00	73.02	1.00	43.45
2017	33.73	100.00	73.09	1.00	43.47
2018	33.43	99.09	72.43	1.02	43.47
2019	31.55	93.55	68.36	1.19	43.45
2020	26.78	79.40	58.03	1.72	43.40
2021	22.67	67.22	49.11	2.55	43.32
2022	12.22	36.14	26.40	4.19	43.15
2023	5.56	16.15	11.86	6.31	42.94
2024	2.52	7.09	5.23	8.64	42.71
2025	1.33	2.94	2.28	11.06	42.47
2026	0.79	1.54	1.23	13.52	42.22
2027	0.64	0.70	0.68	15.99	41.97
2028	0.46	0.47	0.47	18.47	41.73
2029	0.62	0.62	0.62	20.95	41.48
2030	0.47	0.47	0.47	23.43	41.23
2031	0.62	0.62	0.62	25.91	40.98
2032	0.47	0.47	0.47	28.39	40.73
2033	0.62	0.62	0.62	30.87	40.49
2034	0.47	0.47	0.47	33.35	40.24
2035	0.62	0.62	0.62	35.83	39.99

Table 8.1. (Page 2) SLEUTH Growth Coefficients Updated at each time step

Year	Diffusion	Spread	Breed	Slope Resistance	Road Gravity
2036	0.47	0.47	0.47	38.31	39.74
2037	0.62	0.62	0.62	40.79	39.49
2038	0.47	0.47	0.47	43.27	39.25
2039	0.62	0.62	0.62	45.75	39.00
2040	0.47	0.47	0.47	48.23	38.75
2041	0.62	0.62	0.62	50.71	38.50
2042	0.47	0.47	0.47	53.20	38.25
2043	0.62	0.62	0.62	55.68	38.01
2044	0.47	0.47	0.47	58.16	37.76
2045	0.62	0.62	0.62	60.64	37.51
2046	0.47	0.47	0.47	63.12	37.26
2047	0.62	0.62	0.62	65.61	37.01
2048	0.47	0.47	0.47	68.09	36.77
2049	0.62	0.62	0.62	70.57	36.52
2050	0.47	0.47	0.47	73.05	36.27
2051	0.62	0.62	0.62	75.54	36.02
2052	0.47	0.47	0.47	78.02	35.77
2053	0.62	0.62	0.62	80.50	35.52
2054	0.47	0.47	0.47	82.99	35.28
2055	0.62	0.62	0.62	85.47	35.03
2056	0.47	0.47	0.47	87.95	34.78
2057	0.62	0.62	0.62	90.44	34.53
2058	0.47	0.47	0.47	92.92	34.28
2059	0.62	0.62	0.62	95.39	34.03
2060	0.47	0.47	0.47	97.64	33.78
2061	0.62	0.62	0.62	99.23	33.54
2062	0.47	0.47	0.47	99.83	33.29
2063	0.62	0.62	0.62	99.97	33.04

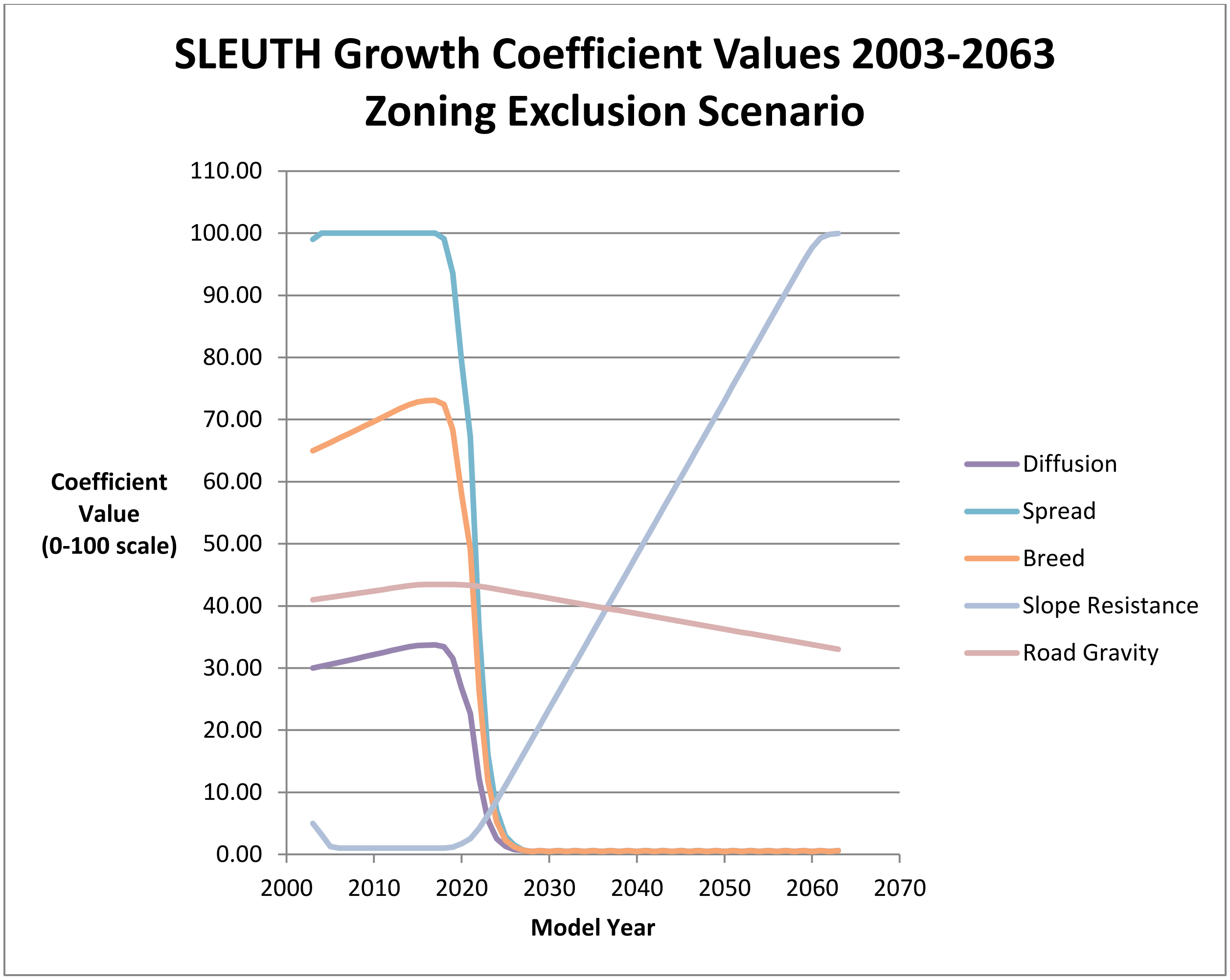

Figure 8.1. SLEUTH growth coefficient values for each model run year

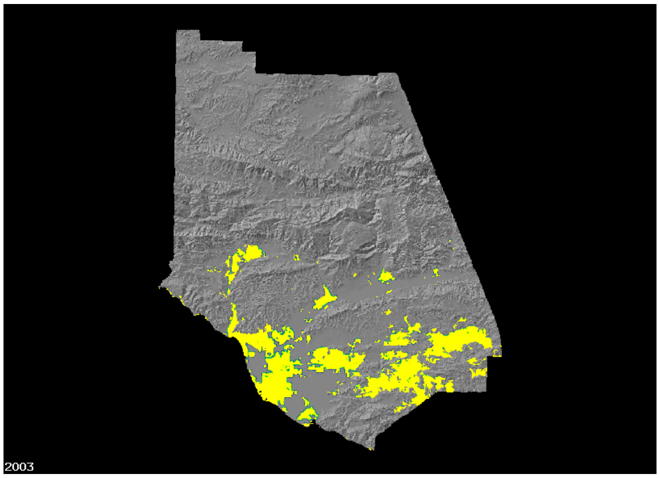

Figure 8.2: Ventura County-wide SLEUTH model results at simulated year 2003

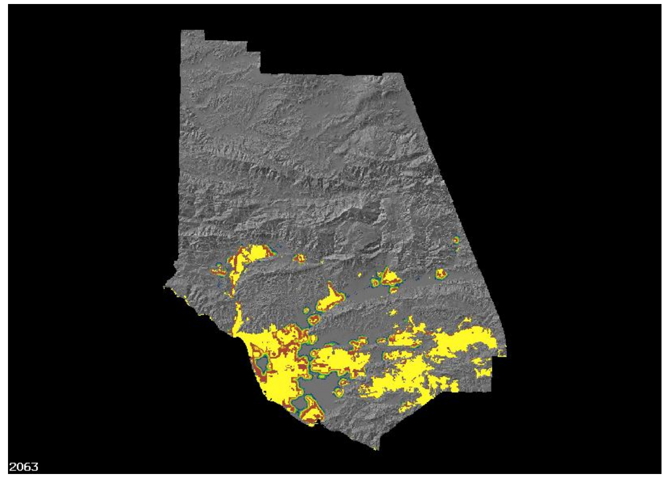

Figure 8.3: Zoning Exclusion Scenario Ventura County-wide SLEUTH model results at simulated year 2063

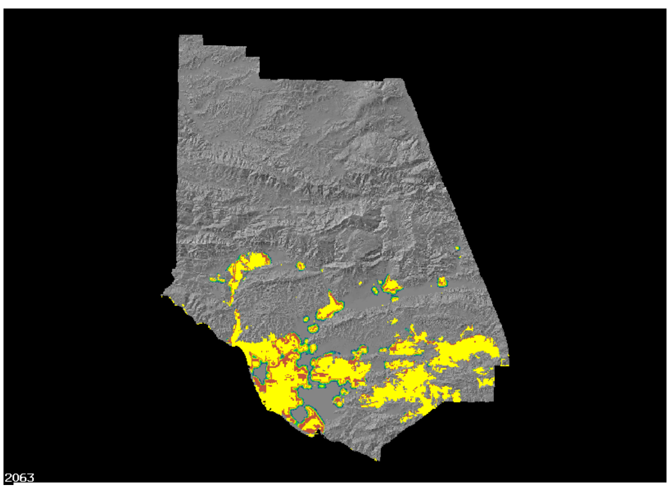

Figure 8.4: 75 Percent SOAR Exclusion Scenario Ventura County-wide SLEUTH model results simulated at year 2063

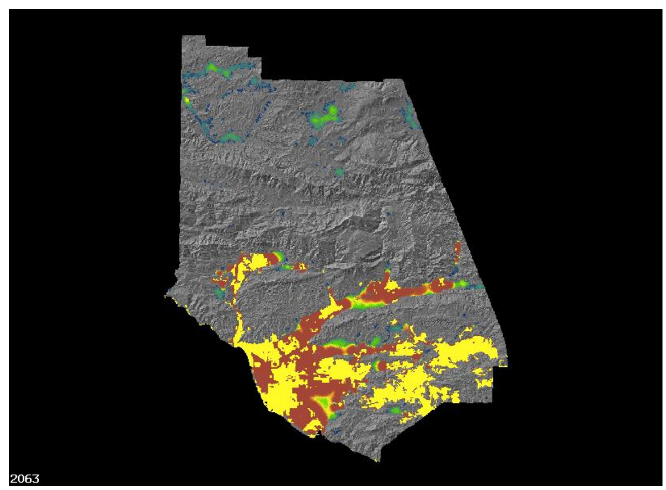

Figure 8.5: Zero Exclusion Scenario Ventura County-wide SLEUTH model results at simulated year 2063

Comparison of Three Exclusion Scenarios

It is important to note that the SLEUTH analysis is conducted at the county scale then is constricted to a narrow area of the model's study area for this project's analysis. This is a benefit of the SLEUTH model in that it takes a regional approach to development prediction. The Exclusion layer for the 75 percent SOAR scenario provides interesting trends on a county-wide scale; however, because this project's ROI is entirely within this SOAR boundary, it does not differentiate parcels from one another based on the Exclusion layer values. Thus, all parcels within the ROI possess an Exclusion layer value of 75 percent for this scenario. Despite this lack of differentiation within the exclusion layer, other factors within the model set parcels apart, and a lack of development pressure within the study area can still provide compelling results. Similarly, all parcels within the zero exclusion scenario are assigned an exclusion value of zero.

Figure 8.6 shows the Spread and Slope Resistance growth coefficients for each of the three exclusion scenarios: zoning, zero, and 75 percent SOAR. The Spread coefficient is most indicative of growth in the model because a majority of the growth in the model occurs as edge growth and is highly influenced by this coefficient. Note the intersection of the spread and slope resistance curves for each scenario; the 75 percent exclusion occurs at approximately model year 2020, the zoning exclusion intersection occurs at model year 2025, and the zero exclusion scenario occurs at model year 2032. Thus, the more restrictive the exclusion layer is, the less developable land in that scenario, and the earlier the model projects development build out will occur.

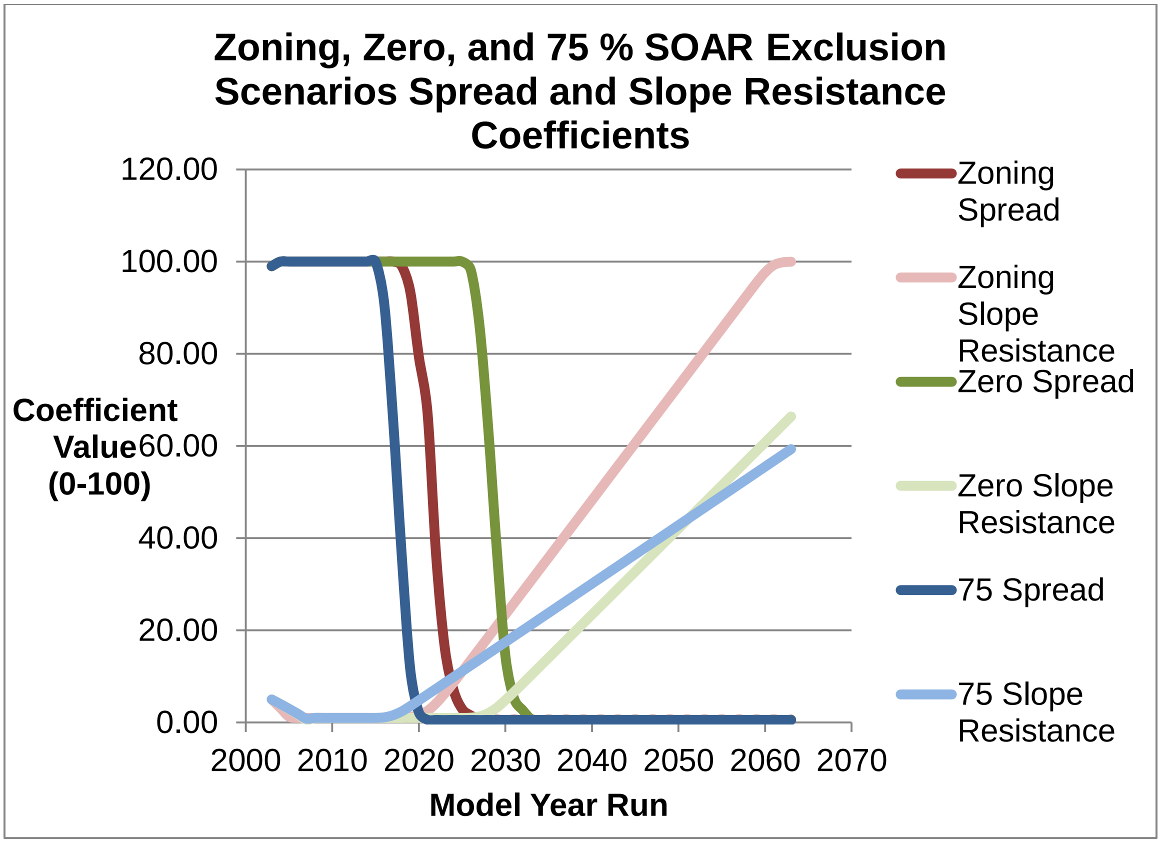

Figure 8.6. Spread and Slope Resistance growth coefficients for each of the three exclusion scenarios. The intersection of each set of Spread and Slope Resistance coefficients approximates the build out date in the model under each scenario, when there is very little developable land.

SLEUTH Development Prediction Trends

The development probability results from the primary exclusion scenario did not predict high average development probabilities across the study area. For instance, in the mainstem, roughly 38 percent of parcels have virtually no development pressure and only 37 out of 487 parcels (7 percent) have a very high development probability. Within the tributaries, nearly half of parcels (43 percent) have virtually no development pressure, but a slightly larger percentage, 16 percent, have a very high development probability.

Development probabilities in both the mainstem and tributaries are influenced most by the proximity to existing urban areas and to a lesser extent, proximity to major roads. Generally, the high development probabilities are seen near each of the existing primary urban centers of Ventura, Santa Paula, and Fillmore. This is seen in Figures X-X [sleuth results ventura, santa paula, fillmore] where higher development probabilities are seen in parcels closest to the SLEUTH urban layer. Major roads that influence urban development include State Highway 126 which parallels the river on the north side in much of the study area (Figures X-X [all main and trib figures in results]), Highway 150 which connects northern Ventura County to the Santa

Paula area (Figure X [Santa Paula trib results figure]), and Highway 23 which originates in Fillmore and traverses south (Figure X [Fillmore/Piru mainstem results]). The influence of Highway 126 is evident in the area between Santa Paula and Fillmore. Highway 150 and proximity to Santa Paula have created high development probabilities in the Santa Paula Creek tributary area (Figure SP Trib). Finally, proximity to Highway 23 results in higher development probabilities for parcels in southern Fillmore and neighboring urban lands to the south of Fillmore (Figure X Fillmore/Piru).

Limitations and Advantages of SLEUTH Analysis:

A primary assumption of the SLEUTH model is that historical land use patterns with the addition of a semi-permeable exclusion layer that accounts for current land use policies, will be a good prediction of future development. While development can be somewhat unpredictable within the constraints placed on properties by land use policies and regulations, historic development patterns are good evidence as to how urban development will proceed in the future. An exception to this is when land use policies change significantly and are restrictive enough to influence development patterns. While there have been relatively recent shifts in land use policies in Ventura County like the SOAR initiative and the LCA, the long term influence they will have on development patterns can only be estimated. Because of this, there is no way to accurately determine the influence historical trends have on predicting future urbanization.

Because of the relatively small size of the Santa Clara River floodplain, the SLEUTH model results may be less accurate than other development predictions done at a larger spatial scale. While it has been run numerous times all over the world, its ability to predict development at a range of spatial and temporal scales has been under scrutiny. SLEUTH is typically run for large regional areas, but the scientific community has investigated its efficacy in accurately predicting growth at smaller scales (Jantz et al., 2003). The literature suggests SLEUTH may be more appropriate for large-scale development prediction. One study found that it was not successful in pinpointing the exact location of development at a pixel scale, but found that the accuracy improved significantly when the analysis was generalized to meaningful spatial units such as USGS Hydrologic Units (Jantz et al., 2003). This argument is bolstered by the work of Trent Otis who looked at the accuracy of SLEUTH over three spatial resolutions (150m x150m, 300m x300m, and 600m x600m). His work suggests that SLEUTH is indeed more effective at broader scales and has difficulty in accurately simulating parcel-level changes; however, this inaccuracy can be smoothed over if a coarser scale resolution is used (Otis, 2012).

Another limitation of SLEUTH stems from how it operationalizes growth processes and how this may limit certain kinds of growth such as low-density development. Jantz et al. believe low-density development is underrepresented despite it being accounted for by the dispersion and breed coefficients. They note that the SLEUTH code gives precedence to edge growth, limiting its ability to simulate low-density development (Clarke et al., 1997). This is because the urban pixels produced by the breed and dispersion parameters are stochastic and are likely filtered out unless they are repeatedly selected by multiple Monte Carlo iterations (Jantz et al., 2003). Within the context of this project, the inability to predict low density development is not a major limitation. The reason for this is that the end goal of using SLEUTH is to predict high density development that would result in the construction of structural flood control effectively reducing the size of the floodplain.

Despite some of the scientific findings on the predictive abilities of SLEUTH being less than desirable, the existence of these detailed analyses specifying the strengths and weaknesses of the model is an advantage in itself. Acknowledging SLEUTH's inherent limitations, which have been noted by other researchers, is important in analyzing the model's results.

8.3 Development Pressure Methodology Comparison: SLEUTH and Weighted Overlay Analysis

Conceptual Comparison

Two development prediction methodologies were pursued within the ROI, a WOA and the SLEUTH Urban Growth Model. Each methodology offers a unique perspective and has inherent advantages and disadvantages. Neither methodology can be determined as more accurate; the hope in undertaking both analyses was to strengthen the parcel prioritization recommendations by approaching the problem with different tools.

The WOA can be thought of as a risk assessment that produces output scores designed to prioritize parcels based on known risk factors with high specificity to the study area. It is important to note that the WOA lacks a defined time horizon to base its predictions on. The WOA relies primarily on current features and conditions, such as parcel size and levee tie-in capability, that provide a spatial gradient of development risk depending on a parcel's proximity to these features. The WOA is also heavily influenced by current land use policies such as General Plan land use designations, county zoning, and development restrictions in the 100 and 500-year floodplain. Both methods rely on similar factors to determine the likely locations of future development; however, the WOA relies more heavily on current data while the SLEUTH model is heavily dependent on historical patterns of development and broad scale land use policy.

The SLEUTH model looks at threat of development primarily at a regional scale, even though its unit of analysis is pixel based that is set at a desired resolution. SLEUTH produces predictions in the form of development probabilities with a fixed time horizon. The SLEUTH model relies on historical urbanization data to calibrate a model that is congruent with the types and magnitudes of growth that have occurred in the past. This is achieved by using a set of calibrated growth coefficients derived from historical data and current data on land use change, restrictions, roads, and urban boundaries. Both the WOA and SLEUTH models incorporate the development limitations of zoning restrictions.

Both models have advantages and disadvantages that result from their differing structures, components, and inputs. The WOA's extent was restricted to the study area and conforms to the unique characteristics of this area. The analysis of the SLEUTH model, on the other hand, occurs at a county-wide scale and is later clipped to the ROI to display parcel specific results.

One particular weakness of the WOA stems from the difficulty in finding scientific literature or other justification for the distances associated with input factor scoring. For example, the difference between a score of 1 or 2 could be based upon a subjective distance such as a quarter mile. This could lead one to argue that some aspects of the spatial analysis are somewhat subjective. While the distances or delineation of various priority areas may be somewhat subjective, the factors that influence growth within the WOA analysis have been validated by experts familiar with local development pressures and restrictions. The selection and weighting of the seven factors in the WOA were heavily influenced by the input and expertise of the advisory group from the Ventura County Planning Department and Ventura County LAFCO. This group has intimate knowledge of long-term development patterns and obstacles that can impede development because of their familiarity with land use policy implementation and permitting.

Where the WOA is subjective in scoring various distances, SLEUTH's reliance on historical datasets and calibrated coefficients may be a more defensible approach. However, SLEUTH's rigid data input needs do not allow flexibility in tailoring development threats to the specific ROI. For instance, the Slope layer likely has very little impact on the model because of the lack of variation in these layers within this project's ROI. The SLEUTH model lacks the transparency that allows the determination of why a particular pixel or even parcel were given the probability they were assigned. Although the growth coefficients do provide some insights, this is not possible with any degree of certainty for SLEUTH outputs. The WOA does allow the examination of how each parcel scored among its seven input factors. Additionally, SLEUTH relies on historical datasets to calibrate the model. Current development patterns may not follow historical trends due to changing social or economic conditions.

Although both sets of analyses are used in peer reviewed literature, SLEUTH represents a consistent methodology that is scrutinized, updated, and in broad use by the scientific community. It has successfully simulated urban change in the San Francisco area between 1900 and 1990 and the Baltimore and Washington DC area. There has been extensive analysis on the methodologies used by SLEUTH (Jantz et al., 2003). Its wide use can be attributed to its success with regional scale modeling, its ability to incorporate different levels of protection of different areas, and the relative ease of computation and implementation (Jantz et al., 2003). Finally, SLEUTH incorporates many complex inputs, influences, and tools including stochastic processes and sensitivity analysis that add to the credibility of its results.

Comparison of Results

Generally, SLEUTH predicts much lower development pressure in the ROI than the WOA. Using SLEUTH, only 32 percent of parcels were predicted to have a development probability greater than 30 percent with the majority of parcels having a less than 5 percent probability of being developed. This is likely because SLEUTH projects a majority of development occurring in northern Ventura, Oxnard, and Moorpark.

SLEUTH was much more impacted by major roads than the WOA model because local roads were not accounted for in the SLEUTH analysis. Comparing a parcel's development pressure for each model cannot be achieved in a meaningful way because the output units are different (probabilities and scores).

8.4 Hydrology Analysis: Potential for Downstream Flood Reduction Benefits

Fluvial systems are difficult to model because of temporal and spatial variability. Scouring, sloughing, and sedimentation alter channel bottoms and cause channel migration that is difficult to represent in one model. Because of data and modeling limitations, many assumptions were made for this analysis. The data used in this project was for a 100-year flood event in a steady state condition. This infers that flow rates, floodway and floodplain delineations, and bottom contours remain constant through time. These assumptions infer that erosion, scouring, and sedimentation are not occurring causing the river to change course. Additionally, the assumption was made that the water table would be near or at the surface of the river bottom and that groundwater recharge was assumed to be zero or close to zero. Groundwater recharge was left out of the analysis for these reasons. These assumptions simplify the hydrological analysis, but fail to capture some inherent benefits that floodplain inundation provides to the surrounding area (i.e. groundwater recharge, sedimentation, erosion). For this project, the only benefit the hydrological analysis identified was flood volume reduction. Incorporating more floodplain benefits would strengthen analysis, but require additional resources. It is recommended that more analysis be done if other floodplain benefits are to be considered.

To identify flood volume reduction benefits on a per parcel basis, one would need to determine how much water is added to the system during a flood event when a parcel is removed from the floodplain. This could be done in a model such as MIKEFLOOD by removing an individual parcel from the floodplain during a 100-year flood simulation and recording the volume of water discharged at the mouth of the river over some period of time. The difference between the discharge volume when the parcel was in the floodplain and when the parcel was removed from the floodplain would be the flood reduction benefit. This type of analysis requires extensive hydrologic modeling and data beyond the scope of this project.

Hydrologic data as well as modeling resources limited hydrological analysis for the project. Only steady state velocity vectors and flood height data were available for a 100-year flood event along the mainstem of the Santa Clara River. A 500-year flood event analysis would be best; however, a 100-year flood model suffices because of the considerable overlap between the 100-year and 500-year floodplains. Although the methodology mentioned above would be optimal to identify how individual parcels alter downstream flood volumes, this analysis was not feasible given the project timeline.

Using directional magnitude arrows with average floodwater velocity and heights for individual parcels, 98 parcels with flood reduction benefits were selected. Parcels with flood reduction benefits typically occurred in the widest stretches of the floodplain, where floodwater could spread and inundate the floodplain fringe. This allowed for floodwater to slow and be held for some period of time before re-entering the floodway. The 98 parcels selected in this analysis represent a conservative selection of parcels with flood reduction benefit. Only parcels that diverted water away from the floodplain, slowed water, and held some volume of water were selected. This method of flood benefit designation serves as a preliminary analysis for which more robust analysis can build off of. Further analysis is suggested to better identify and rank parcels along the mainstem of the Santa Clara River and its tributaries.

Conserving small numbers of individual parcels identified in this project will not provide significant flood benefits. The largest parcel in our analysis is less than one percent of the overall area of the floodplain. In order to provide floodplain benefits, a large portion of the floodplain needs to be conserved. Due to variability across fluvial systems, there is no standard percentage in the literature that describes the necessary level to keep natural flood reduction benefits intact. Removing all parcels in the project ROI from the floodplain with hard structures such as levees would eliminate any natural flood reduction benefits the floodplain currently provides the region. Therefore, conserving all parcels in the project ROI in the floodplain has inherent value and natural flood reduction benefits. Future hydrological modeling could be conducted to find the percentage of parcels that need to be conserved along the Santa Clara River's floodplain to keep the current natural flood reduction benefits. The purpose of the hydrological analysis in this project was to identify parcels that if removed from the floodplain would remove the largest degree of flood benefit.

8.5 Easement Evaluation

The four methods used to determine the value of agricultural conservation easements (ACEs) in the Santa Clara River floodplain resulted in a wide range of easement estimations, ranging from $0 (no value to the development right) to $57,000/acre, (greater than the sale price of many of the floodplain properties). The true value of an easement lies somewhere in that spread, and will likely vary depending on a parcel's distance to urban boundaries, lot size, and local development pressures (Lynch & Lovell 2002; Plantinga & Miller, 2001). For this reason, developing a more spatially explicit easement valuation model that could take these factors into account, would be useful in future easement negotiations.

Additionally, factoring in the uncertainty of future agricultural rents would be important to include in future analysis. For both the income capitalization method and the direct valuation of the development right, agricultural rents were assumed to remain constant throughout time. This is highly unlikely as demand will likely increase into the future and supply will likely shift with a changing climate.

Beyond the market drivers that determine what the price of an ACE will be, it is important to consider the social value that will be gained from purchasing these easements. Not only does agriculture directly support the local economy through food production, it also supports it indirectly through sales and employment from supporting businesses (Kambara et al. 2008). Other social benefits, like flood regulation, water infiltration, pollination, and open space, are more difficult to quantify, but are likely to be undersupplied without intervention from governments and non-profits (Plantinga & Miller, 2001). Because of this, the need for an agricultural conservation easement program will exist in the Santa Clara River floodplain as long as the market determined easement value is less than the value of these social benefits.

8.6 Final Recommendations- Top Priority Parcels

Both development models used in this project have provided valuable insights into development pressure for parcels in the ROI. However, each model has its limitations as outlined above. By grouping high priority parcels that overlap in both models and combining this grouping with hydrological analysis, top priority parcels have been highlighted. It is recommended that initial easement acquisition effort be focused on these top priority parcels. After this initial acquisition is over, The Nature Conservancy must use their knowledge of both development models and determine how to use these results to support their goals and objectives. After choosing a method with which to base their acquisitions on, further easement purchases should be focused on the parcels that lie in Tier 1 of either development/hydrological grouping.

8.7 Recommendations for future research

Climate Change and Sea Level Rise

Global climate change is occurring altering air and oceanic temperature, precipitation, sea level, and extreme weather events across the planet. Over the past half century global average surface temperatures as well as global average sea level have increased; this increase has raised concerns about both environmental and social impacts to future generations (IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC) Climate Change 2007: Synthesis Report suggests that the North America's western mountains will experience a decrease in winter snowpack, ultimately leading to more winter flooding and reduced summer flows (IPCC, 2007). While the effects of global climate change and associated changes in precipitation patterns and sea level rise are important in planning future land uses, the data available for regional impacts did not justify the inclusion of these effects in this project.

The United States Environmental Protection Agency has predicted that climate change will cause northern states to experience warmer temperatures while southern states, especially in the west, will see drier weather. Additionally, large precipitation events are likely to increase in the United States (Karl et al., 2009). Because the Santa Clara River is located in a region that global climate models predict to be drier, but also experience more frequent large precipitation events, it is difficult to predict the severity of future flood events.

Current climate models have difficulty in modeling regional variability, which increases uncertainty about how impactful climate change will be on local levels. Climate change may impact regions separated by relatively small distances (e.g. 200 miles) differently in the southwestern United States. The Santa Clara River watershed may or may not experience changes in precipitation from climate change, making it difficult to predict how flooding events will change in the future. Because of this uncertainty, we have not included climate change into our models and results. If regional climate modeling is completed that is capable of more accurately predicting the frequency and magnitude of future precipitation patterns in Ventura County, it could be valuable in planning for future flood events along the Santa Clara River.

Sea level rise has the potential to impact coastal flooding around fluvial systems like the Santa Clara River. However, a recent study by the ESA-PWA consulting group showed that sea level rise is unlikely to impact flooding events near the mouth of the Santa Clara River in the future. Sediment loading around the mouth is predicted to actually reduce the impact sea level rise has on the floodplain by reducing inundation during extreme precipitation events. Because of this, it was decided to leave sea level rise out of the project's parameters.

Applying this methodology to different situations

The framework and methodology of this project may be applicable and helpful in the prioritization of lands for protection in other locations with floodplain benefits at risk from increasing development pressure. However, adjustment will need to be made to account for different local land uses, urban growth policies, specific hydrologic conditions of the river systems and watersheds, and the unique characteristics that influence the price of land in the area.

Conclusion

This project served to provide recommendations for acquisition of agricultural conservation easements along the Santa Clara River in Ventura County, CA, that would aid TNC in the implementation of the Natural Floodplain Protection Program (NFPP). Through communication with a variety of stakeholders, it was concluded that development pressure and potential benefit to downstream flood reduction are the major factors considered in parcel prioritization for this project. Two development pressure prediction models (WOA and the SLEUTH models) were used to estimate each parcel's development pressure. These two development models complement each other and work in conjunction to increase the robustness of our results. The results from both development models were combined with parcels selected in the hydrology analysis. In this way, development pressure analysis was combined with potential to provide benefits of downstream flood reduction analysis to tier parcels and ultimately create a top priority grouping of parcels for TNC. Additionally, several easement valuation methodologies were compared to provide TNC with an estimate of easement value in the study area. The results from all analyses were compiled into a database with additional relevant information to guide TNC in their easement acquisition. The analysis conducted for TNC can help guide future easement acquisition along the Santa Clara River and act as a framework for similar projects in the future.

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Appendix A. SLEUTH Model

Five coefficients determine the magnitude of various types of growth within the model. These coefficients are refined during calibration mode by comparing historical land cover change and are optimized to best predict present urban development conditions.

The five coefficients that determine the various types and magnitudes of growth within the model include dispersion, breed, spread, slope, and road gravity. The dispersion coefficient governs spontaneous growth and controls the number of times a pixel will be randomly selected for possible urbanization. The breed coefficient determines the probability of a spontaneous growth pixel becoming a new spreading center, and as a result, can influence the number of road trips taken. For example, if a new area is developed outside an urban area, more vehicle trips will likely be necessary to accommodate the needs of those living or working there. The spread coefficient determines how much edge growth will occur within the model. Spreading centers are a cluster of two or more urban pixels within a 3x3 matrix. The spread coefficient determines the likelihood that any pixel within a spreading center will generate an additional urban pixel in its neighborhood. The slope factor is determined by the critical slope value and the slope coefficient. The critical slope value is the value at which development is impossible. The slope coefficient is a function of the relative pressure to build on steeper slopes given the proportion of flatland and steep terrain that is proximal to an established settlement. The slope coefficient acts as a multiplier with a value between 0-100. If the slope coefficient is high (50-100), the more likely pixels with large slope values will be developed if they are near an urbanized development (See Figure A.1).

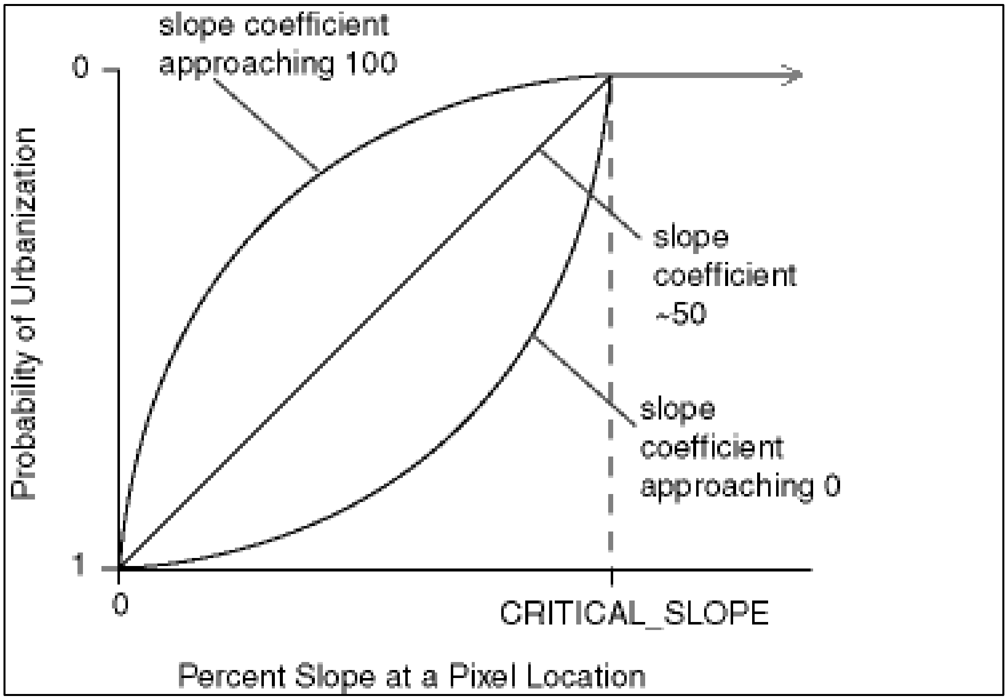


Figure A.1: Relationship of Slope coefficient to Probability of Urbanization with Increasing Slope (NCGIA, 2013)

The Road Growth coefficient is determined by methodically determining the distance to the nearest road or terminating its search once it has hit a maximum distance threshold. The maximum search distance is determined as a proportion of the image dimensions by the following formula:

rg_value = (*rg_coeff*/MAX_ROAD_VALUE) * ((row + col) / 16.0)

Where MAX_ROAD_COEFF_VALUE is defined as 100, and (row, col) are the row and column pixel counts, so that *rg_value* at its maximum (*rg_coeff* == 100) will be 1/16 of the image dimensions. If the rg_coeff value is less than 100, then the rg_value will be some proportion less than 1/16 of the image dimensions.

Once *rg_value* is found, it is used to determine the *max_search_value* by the following:

max_search_index = 4 * (*rg_value* * (1 + *rg_value*))

Where *rg_value* defines maximum number of neighborhoods from selected newly urban pixel to search for a road. Neighborhoods are defined as the grouping of cells that directly surround a pixel extending outward and doubling with each additional neighborhood. For instance, the first neighborhood (*rg_value* = 1) is made up of the selected urban pixel's adjacent 8 cells. The second neighborhood (*rg_value* = 2) would be the 16 pixels outwardly adjacent to the first neighborhood, etc. Thus, the search for a road continues until either a road is found, or the search distance is greater than *max_search_index* (Gigapolis, 2013).

Growth Types:

Spontaneous Growth: Reflects a small probability of any cell becoming urbanized in any time step. The probability is dependent on the values of the dispersion coefficient and slope coefficients, but is also a stochastic process. Cells that are already urban or are excluded are omitted from the effects of spontaneous growth. An example of this type of growth is shown in figure A.2.

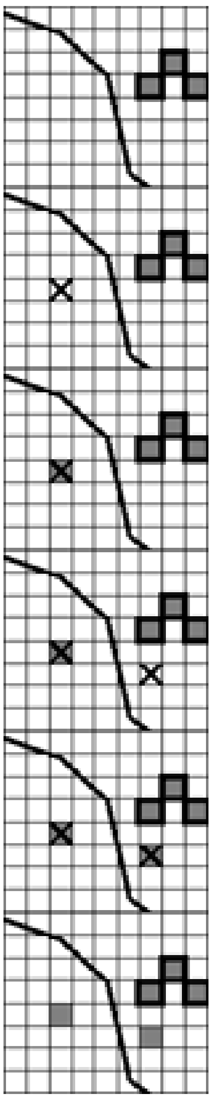


Figure A.2: Spontaneous Growth within the SLEUTH Model (Project Gigapolis 2013)

New Spreading Center Growth: This type of growth follows spontaneous growth and determines whether or not newly urbanized cells will become spreading centers. The probability of this occurring is governed by the breed coefficient and can only occur if two of the eight adjacent cells are available for urbanization based on exclusion and slope. A new spreading center is defined as three or more urbanized cells. An example of this type of growth is shown in figure A.3.

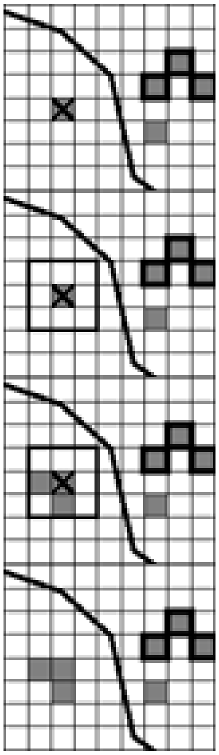
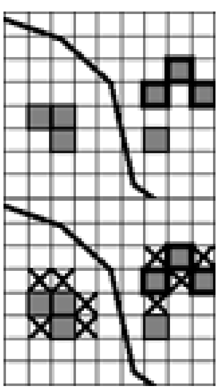


Figure A.3: New Spreading Center Growth within the SLEUTH Model (Project Gigapolis 2013)

Edge Growth: Edge growth builds on current urban areas and new spreading centers. A primary requirement for this type of growth is having two urbanized neighboring cells. The probability of becoming urbanized once this condition has been met is governed by the spread coefficient and slope coefficient. Figure A.4 provides a visualization of how this type of growth occurs.



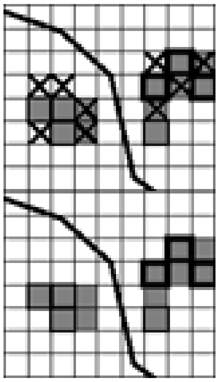
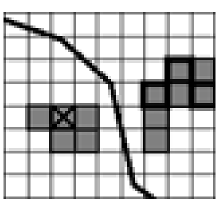


Figure A.4: Edge Growth within the SLEUTH Model (Project Gigapolis 2013)

Road-Influenced Growth: Road-influenced growth builds on all types of growth previously discussed as well as the past and present transportation network to predict future development. A detailed step-by-step explanation of road-influenced growth is provided in Figure A.5 In previous versions of the SLEUTH model, road weighting was used to capture the differences in road use to modify the value of the “random walk” distance (the path along a road a temporarily urbanized cell would take to potentially start a new spreading center). For example, a major road like Highway 126 may have a longer random walk distance than a small residential road. However, research conducted at the University of Pennsylvania and UCSB on SLEUTH determined that road weighting had very little influence on the overall system output. The latest version of SLEUTH uses road weighting instead to determine the likelihood of a new spreading center at the end of the random walk. In the interest of simplifying data inputs, roads were weighted on a binary basis, 0 as non-road, and 100 as road, thus details such as road size and quantity of daily trips were not accounted for.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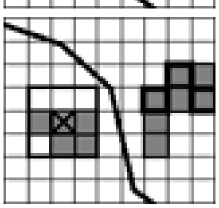
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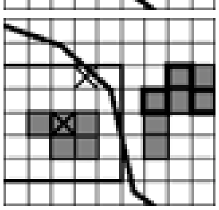
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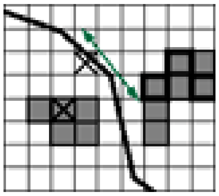
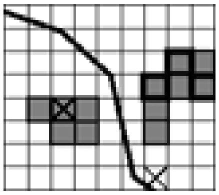
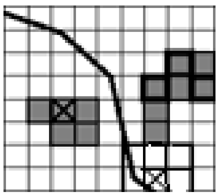

d.


e.


f.


g.

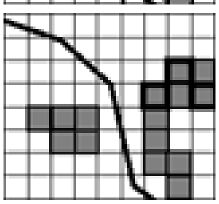

h.

Figure A.5: Road Influenced Growth within the SLEUTH model begins with a.) A newly urbanized cell selected with a probability defined by the breed coefficient b.) The existence of a road is sought within the newly urbanized cell's neighborhood c.) If a road is found within a given maximum radius as determined by the road gravity coefficient, a temporary urban cell is placed on the road d.) Next this temporary cell conducts a random walk along the road network, and the number of steps taken is determined by the road gravity coefficient e.) and f.) The final location of the temporary urbanized cell then becomes a new urban center if one of its neighboring cells is available for urbanization (randomly picked among possible candidates g.) and h.) If more than one adjacent cell is available for urbanization these cells become urbanized as well. The number of times a newly urbanized cell develops within a given time step is also determined by the breed coefficient. (Project Gigapolis 2013)

Table A.1 provides a summary of how each coefficient influences each types of growth.

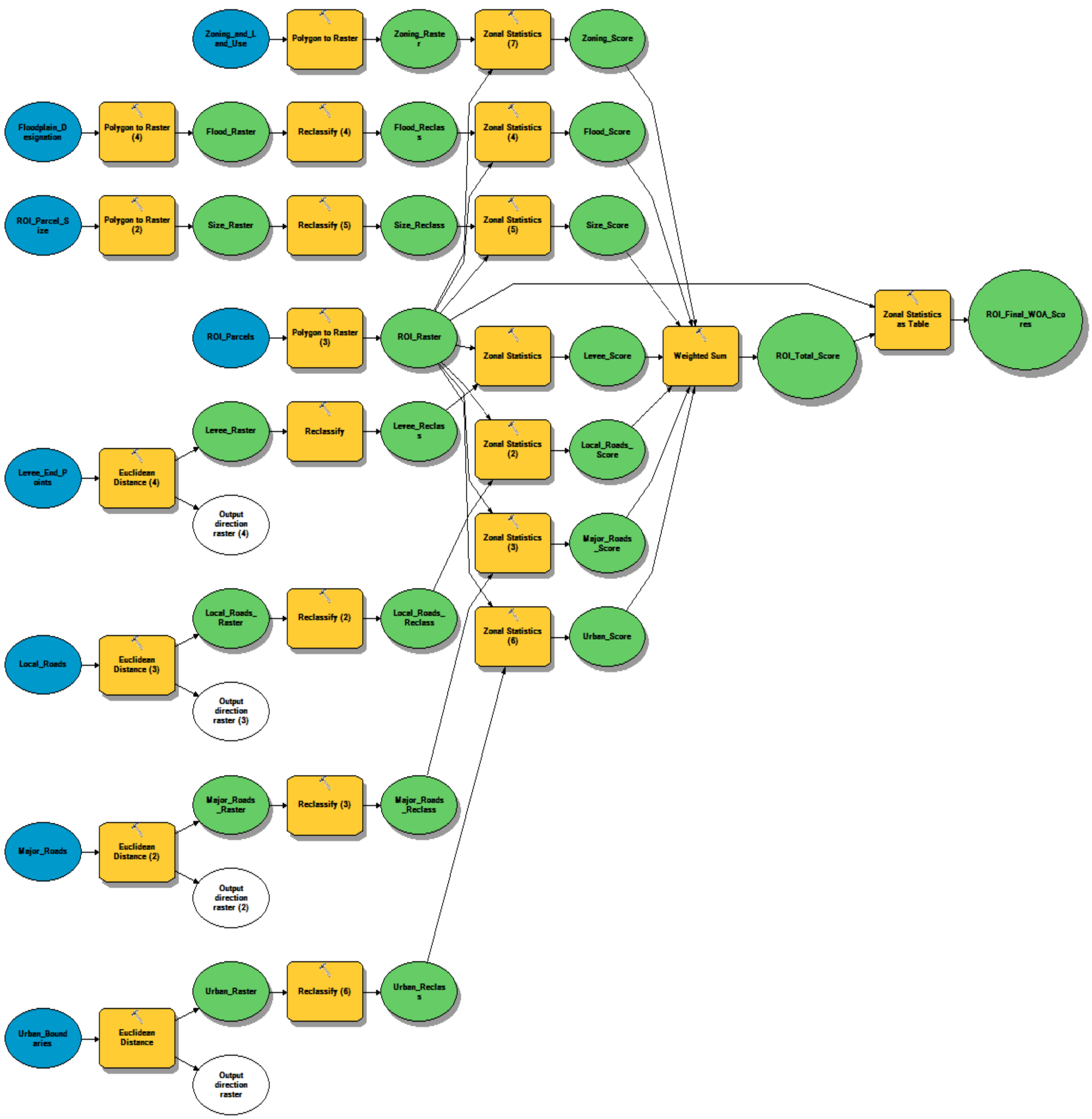
Table A.1: Coefficients and the Types of Growth they Govern

Coefficient	Types of Growth
Dispersion	Spontaneous Growth
Breed	New Spreading Center, and Road Influenced Growth
Spread	Edge Growth
Slope	Spontaneous Growth, New Spreading Center, Road Influenced Growth, Edge Growth
Road Gravity	Road Influenced Growth

Appendix B. Building the Weighted Overlay Analysis Model

The purpose of this appendix is to show how the Weighted Overlay Analysis (WOA) model was built for similar application outside of this project. The WOA model was built using ArcMap 10.1's ModelBuilder. Seven shapefiles were needed to build the model: parcels, county zoning/General Plan land use designations, urban growth boundaries, floodplain designations, major roads, local roads, and levee end points. All shapefiles used in the WOA were clipped to the Santa Clara River Watershed to reduce features for analysis. Only the procedure for building the WOA model used in this project will be outlined below. Data preparation of shape files, reasoning for using this methodology, and data sources will not be discussed. Below is a visual representation of the model.

Seven input factors were used in the model: zoning/land use, urban growth boundaries, parcel



size, floodplain designation, major roads, local roads, and levee end points. These input factors were combined to assign each parcel a single score representing development pressure, Final WOA Score.

Input Factors

Parcels

1. Shapefile was converted to raster data using the Polygon to Raster tool
    a. Value field: APN code
    b. Cell assignment type: maximum area
    c. Priority field: none
    d. Cellsize: 5 ft

Parcel Size

1. Parcels Shapefile was converted to raster data using the Polygon to Raster tool
    a. Value field: shape area
    b. Cell assignment type: maximum area
    c. Priority field: none
    d. Cellsize: 5 ft
2. Raster data was reclassified using the Reclassify tool
    a. Raster data reclassified into four classes
    b. Classified using geometric interval
    c. Larger areas get scored higher than smaller areas
3. Reclassified raster rata was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: mean
    c. Ignore Nodata in Calculation: true

Zoning/Land Use

1. Shapefile was converted to raster data using the Polygon to Raster tool
    a. Value field: zoning/land use type
    b. Cell assignment type: maximum area
    c. Priority field: none
    d. Cellsize: 5 ft
2. Raster data was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: mean
    c. Ignore Nodata in Calculation: true

Floodplain Designation

1. Shapefile was converted to raster data using the Polygon to Raster tool
    a. Value field: zone
    b. Cell assignment type: maximum area
    c. Priority field: none
    d. Cellsize: 5 ft

2. Raster data was reclassified using the Reclassify tool
    a. Raster data reclassified to only represent the 100- and 500-year floodplain
    b. 500-year floodplain score higher than 100-year floodplain
3. Reclassified raster data was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: mean
    c. Ignore Nodata in Calculation: true

Levee End Points

1. Shapefile was converted to raster data using the Euclidean Distance tool
    a. Maximum distance: 2640 ft
    b. Cellsize: 5 ft
2. Raster data was reclassified using the Reclassify tool
    a. Raster data reclassified into three classes
    b. Classified using equal interval
    c. Areas closer to levees scored higher than those farther away
    d. NoData gets the lowest score
3. Reclassified raster data was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: maximum
    c. Ignore Nodata in Calculation: true

Local Roads

1. Shapefile was converted to raster data using the Euclidean Distance tool
    a. Maximum distance: 880 ft
    b. Cellsize: 5 ft
2. Raster data was reclassified using the Reclassify tool
    a. Raster data reclassified into three classes
    b. Classified using equal interval
    c. Areas closer to roads scored higher than those farther away
    d. NoData gets the lowest score
3. Reclassified raster data was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: maximum
    c. Ignore Nodata in Calculation: true

Major Roads

1. Shapefile was converted to raster data using the Euclidean Distance tool
    a. Maximum distance: 5280 ft
    b. Cellsize: 5 ft
2. Raster data was reclassified using the Reclassify tool
    a. Raster data reclassified into three classes
    b. Classified using equal interval
    c. Areas close to roads scored higher than those farther away
    d. NoData gets the lowest score

3. Reclassified raster data was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: maximum
    c. Ignore Nodata in Calculation: true

Urban Growth Boundaries

1. Shapefile was converted to raster data using the Euclidean Distance tool
    a. Maximum distance: 5280 ft
    b. Cellsize: 5 ft
2. Raster Data was reclassified using the Reclassify tool
    a. Raster data reclassified into three classes
    b. Classified using equal interval
    c. Areas close to urban growth boundaries scored higher than those farther away
    d. NoData get the lowest score
3. Reclassified raster data was assigned to each parcel using the Zonal Statistics tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic type: majority
    c. Ignore Nodata in Calculation: true

Combining Input Factors

1. All seven input factor Zonal Statistics were combined using the Weight Sum tool
    a. Weights assigned to each input factor zonal statistic were derived using the Analytical Hierarchy Process
        i. Parcel Size: 0.172
        ii. Zoning/Land Use: 0.334
        iii. Floodplain Designation: 0.099
        iv. Levee End Points: 0.02
        v. Local Roads: 0.04
        vi. Major Roads: 0.055
        vii. Urban Growth Boundaries: 0.279
2. Weighted Sum data was exported into a table using the Zonal Statistic as Table tool
    a. Input raster or feature zone data: Parcels Raster
    b. Statistic Type: mean
    c. Ignore Nodata in Calculation: true
3. Outputs from the Zonal Statistic as Table tool were joined to each parcel in the Region of Interest to give a score to each parcel