LANDSCAPE SCALE MANAGEMENT STRATEGIES

for Arroyo Mocho and Arroyo Las Positas

PROCESS-BASED APPROACHES FOR DYNAMIC, MULTI-BENEFIT URBAN CHANNELS

SAN FRANCISCO ESTUARY INSTITUTE

Prepared for
ZONE 7 WATER AGENCY

SFEI PUBLICATION #714

ACKNOWLEDGEMENTS

SFEI would like to acknowledge Zone 7 Water Agency for funding this exploratory document, particularly Carol Mahoney, Joe Seto and Brad Ledesma. Thanks also to Phil Stevens and the staff at the Urban Creeks Council for their input, as well as Heath Bartosh of Nomad Ecology. This project was made possible by the Alameda Creek Watershed Historical Ecology Study, completed in 2013, which was funded by the San Francisco Public Utilities Commission and Alameda County Flood Control and Water Conservation District, with additional support from Zone 7 Water Agency, Alameda County Water District, and the Alameda County Resource Conservation District.

SUGGESTED CITATION

Beagle J, S Baumgarten, RM Grossinger, RA Askevold, Stanford B. 2014. Landscape Scale Management Strategies for Arroyo Mocho and Arroyo Las Positas: Process-Based Approaches for Dynamic, Multi-Benefit Urban Channels. SFEI Publication #714, San Francisco Estuary Institute, Richmond, CA.

COVER AND REPORT IMAGES

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CONTENTS

1. OVERVIEW

At the request of a number of partners, the San Francisco Estuary Institute (SFEI) recently completed the Alameda Creek Watershed Historical Ecology Study (Stanford et al. 2013). This report builds on findings from the historical ecology study, developing focused technical information to support environmental management of the Arroyo Mocho and Arroyo Las Positas channel reaches managed by the Zone 7 Water Agency (Zone 7) in the Livermore-Amador Valley. This effort is part of an update of the Stream Management Master Plan (SMMP), which defines management goals, objectives, and implementation strategies for the streams, channels and arroyos under its jurisdiction (Zone 7 2006).

This report is intended to help Zone 7 staff address contemporary management challenges by developing a better understanding of their underlying causes, which often include historical land use impacts and underlying physical processes. The aim of this work is to improve the ability of the SMMP to accurately identify both opportunities and constraints associated with strategies for stream management improvement, regarding riparian vegetation and floodplains, and sediment management. Improved understanding may lead to innovative and potentially cost-saving management strategies that can include upstream mitigation of erosion sources (where feasible), restoration of in-channel complexity, and re-connection of streams to floodplains for sediment storage and ecological benefit, among others.

Many of the management challenges on Arroyo Mocho and Arroyo Las Positas involve sediment processes. Watersheds naturally produce, store, and transport sediment. There are a variety of different types of natural inputs of sediment to a watershed, including episodic sources such as landslides, debris flows, and earth flows, as well as chronic sources such as soil creep and bank erosion. Storage of sediment naturally occurs as the inputs from watershed surfaces and channel erosion are transported downstream through the channel network. This occurs on in-channel bars or in wide braided stream reaches, and on off-channel floodplains as high flows deposit sediment adjacent to channels. Some of the sediment produced in the watershed is transported all the way downstream to a receiving water body, such as the Bay. This balance of the production of sediment (the input), minus the storage of sediment, equals the output to a point downstream. Each watershed has a different sediment balance (Input – Storage = Output), based on factors such as bedrock geology, tectonics, climate and the resulting differences in slope, hillslope formations, discharge and channel networks. The sediment balance can change decadally with changes in land and water management and climate.

Human development has altered this sediment balance in Bay Area watersheds in many ways. Increases in impervious surfaces, and impoundments have created an imbalance of water and sediment produced from the watershed, often leading to channel downcutting, or incision. Some sources of sediment production have become more predominant, such as bank erosion from incising reaches of streams, and erosion due to land management such as intensive cattle grazing. The straightening, simplification and leveeing of streams has reduced the ability of channels to sort and store sediment on in-channel bars or to occupy a wide enough corridor to maintain in-channel complexity such as braiding. Instead, sediment is often stored at bridge pilings and other man-made depositional environments. Additionally, channel incision and levee construction have disconnected channels from their adjacent riparian zones, reducing floodplain deposition on the valley floors and limiting access to off-channel habitat for fish and wildlife. These modifications have led to excessive erosion in some reaches of streams, and sediment-starved reaches in others. This imbalance, along with the impoundment of sediment in reservoirs, has reduced overall sediment delivery to the Bay. Thus, management of these systems is complex and difficult.

Flood control managers will continue to face challenges associated with sediment imbalances, but will also be under increasing pressure to develop management regimes that integrate multiple benefits, such as ecological functions (e.g., floodplain and riparian forest habitat), improved water quality, and cost effective flood control. As such, it behooves today's flood control managers to consider multiple benefit approaches when envisioning large-scale redesign plans that are intended to function for many decades.

This report focuses mainly on the storage component of the sediment balance, in the upper part of the Alameda Creek watershed within the Livermore-Amador Valley (the Valley). The study focuses on two creeks in the Valley, Arroyo Mocho and Arroyo Las Positas, with particular attention paid to in-channel erosion and aggradation problem areas as identified by earlier efforts by Zone 7 and others. The report mentions several other creeks draining the upper part of Alameda Creek watershed (Alamo Canal, Tassajara Creek, Collier Creek, etc.), yet remains focused on the valley-bottom reaches of the Arroyo Mocho and Arroyo Las Positas. Through our analyses, and building on research synthesized in the Alameda Creek Watershed Historical Ecology Study (Stanford et al. 2013), we identify long-term geomorphic trends and develop restoration concepts aimed at improving watershed functioning from both a geomorphic and ecological perspective. These concepts provide a starting point for more detailed analysis and modeling, which could lead to more resilient channel re-designs that:

- Integrate multiple benefits (e.g., flood protection, sediment management, groundwater recharge, ecosystem functions, etc.)

- Provide robust ecological functions that sustain native plant and wildlife species
- Increase flexibility to adapt to future climatic regimes
- Reduce maintenance costs

Designing resilient systems within a highly modified setting, such as the Livermore-Amador Valley, requires an understanding of how the systems used to function under more natural conditions, and how they have changed through time (Collins and Montgomery 2001; Grossinger 2012). This perspective provides a framework for developing conceptual approaches that integrate dynamic natural processes within developed landscapes to maximize target functions. To be effective, this thinking must take place at a large scale and consider long term processes and responses (Simenstad et al. 2006, Greiner 2010, Wiens et al. 2012, Parrott and Meyer 2012).

The resilient landscapes approach uses a strong understanding of historical and contemporary physical and ecological drivers to design hybrid landscapes. In the past, watershed modification often involved constraining highly dynamic channels and hillslopes: for example, channelizing alluvial fans, diking wetlands, and leveeing streams. Many contemporary watershed management challenges, such as sedimentation, stream channel incision, bank failures, and flooding, derive directly from these alterations, which often exacerbated "problems" upstream and downstream. Understanding historical landscape patterns and processes helps us to predict how these dynamic systems might respond to future modifications or a changing climate. Historical analysis does not enable us to recreate exact historical configurations, but rather enhances our understanding of underlying physical and ecological processes. While in many cases landscape processes and ecological features have been profoundly altered, in other cases natural processes are still quite active and impactful. To facilitate the recovery of degraded or damaged ecosystems, as well as cost effective flood management, knowledge of the state and evolution of the pre-modified ecosystem and how it has changed is invaluable (Jackson and Hobbs 2009).

Management must be effective over both short- and long-term time frames. Some interventions will necessarily take place at a site scale and over the shorter term, because of time, budget, and land availability limitations. However, to be maximally effective and achieve multiple benefits, short-term management actions should be implemented with a longer term vision in mind (Beagle et al. 2013). The landscape scale approach is also important for identifying opportunities to improve ecological connectivity and long-term adaptability to climate change and other environmental shifts. Some of these opportunities may be critical to the ecological function and resilience of the area, but may not be able to be addressed in the immediate site scale project design. Thus, a central component of translating a resilient landscape perspective to site-scale design is envisioning an adaptable restoration or management process that includes actions that are possible in the short-term but also incorporates a longer-term vision of what is needed at the landscape scale.

This report highlights potential short-term, site scale opportunities along the Arroyo Mocho and Arroyo Las Positas corridors in the Valley. It is also intended as a starting point for developing a vision for a longer-term, landscape scale management approach. The ultimate goals of the approach are to provide multiple benefits, reduce maintenance costs, increase flexibility to adapt to changing climates, and enhance ecosystem functions and resilience.

Report structure

The report is organized around two main questions: 1) How do the physical, ecological, and anthropogenic changes of the Livermore-Amador Valley over the past 200 years, with a focus on Arroyo Mocho and Arroyo Las Positas, contribute to contemporary management challenges? 2) How can we combine our understanding of these historical changes with an understanding of contemporary watershed dynamics to improve watershed and channel functions in the future?

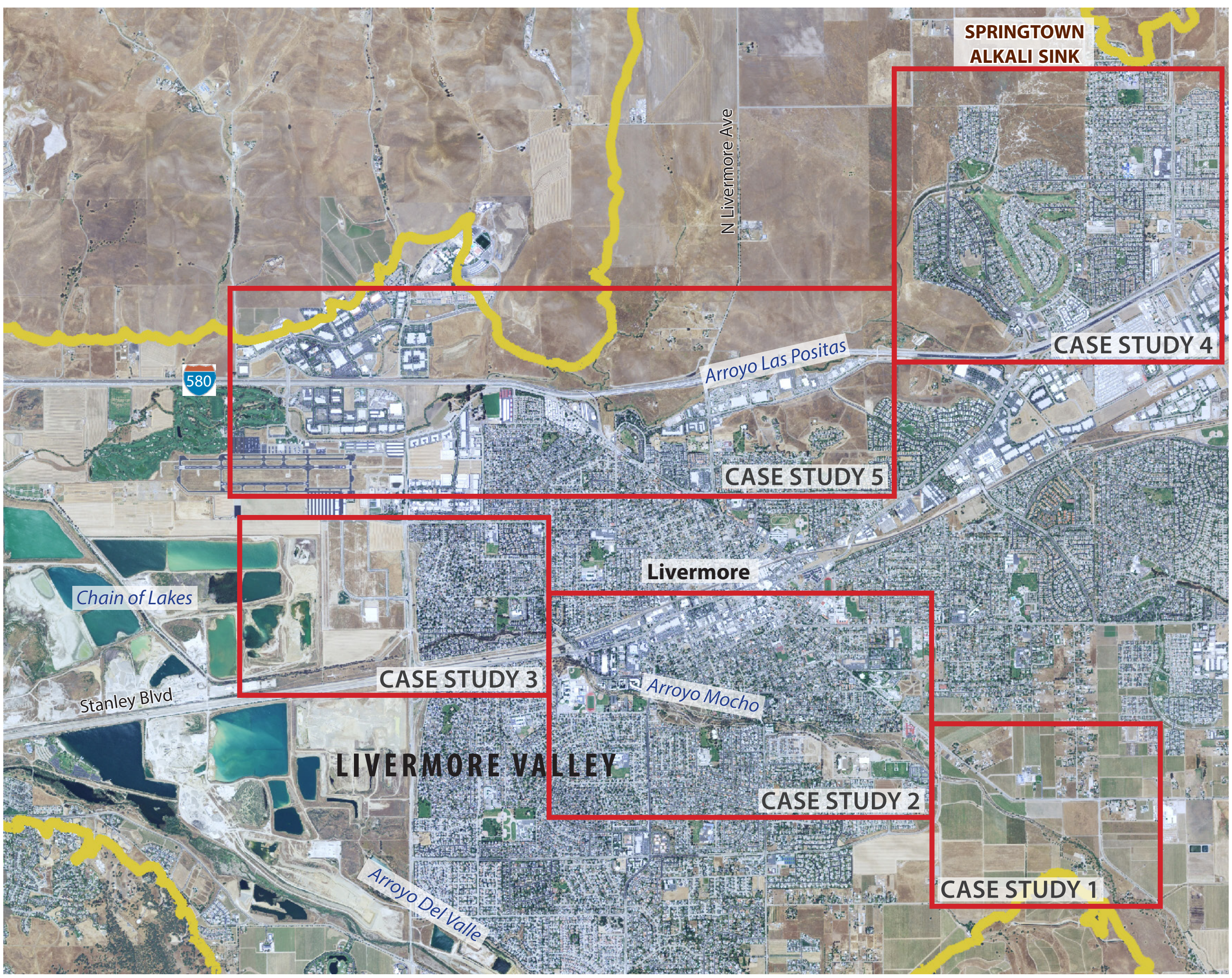
The first section of this report provides an overview of the physical and ecological processes and characteristics that defined the Valley historically. The second section applies this information to two high priority streams within the Zone 7 service area - Arroyo Mocho and Arroyo Las Positas - and discusses a range of potential management strategies.

Methods summary

The historical ecology study of the Alameda Creek Watershed (Stanford et al. 2013) served as a baseline of information for this report, providing a broad array of information about the ecological and physical processes that shaped this watershed. Other key data sources included San Francisco Estuary Institute (SFEI) studies examining sediment dynamics in the watershed, SFEI riparian vegetation surveys (as part of this project), Zone 7 reports and the currently-in-revision SMMP, local expertise from Zone 7 staff, USGS topographic quadrangles, aerial photographs, and a variety of other historical and contemporary reports, data inputs, and field observations. We synthesized historical and contemporary information to 1) examine physical gradients and drivers; 2) analyze hydrogeomorphic, ecological, and land use changes over time; 3) devise landscape-level management strategies; and 4) develop conceptual models illustrating potential landscape trajectories. The conceptual models are designed to enhance the conversation about priority restoration planning, flood protection, and watershed management for the future over both short and longer term time scales. We also surveyed contemporary riparian vegetation in selected areas to improve understanding of the current condition and future potential of riparian vegetation communities.

We examined physical and ecological patterns, processes, and problems throughout the Valley, but we focused our analysis on a 102 km^2 (39 mi^2) rectangular area encompassing the valley-bottom portions of Arroyo Mocho and Arroyo Las Positas surrounding the City of Livermore (Figure 1.1). This area extends from Springtown in the northeast corner to the confluence with the Arroyo Mocho, near the Chain of Lakes (gravel pits). Within this area we focused our analyses on five "case studies" that highlight particular management challenges, physical changes, or restoration/preservation opportunities on varying time scales (see figure 1.1). For a full description of the methods used in the study, see Appendices A and B.

Figure 1.1. The study area focused on a 102 km^2 (39 mi^2) area encompassing much of the valley-bottom portions of Arroyo Mocho and Arroyo Las Positas surrounding the City of Livermore. The thick yellow line at the edge of the Valley indicates the extent of the Alameda Creek Watershed Historical Ecology Study boundary (Stanford et al. 2013). Case studies are outlined in red.



Summary of change and current challenges

The Livermore-Amador Valley has developed rapidly in recent decades, and today contains a complex mix of urban and suburban development, agriculture, and rangelands. For thousands of years before European settlement, the Chochenyo Ohlone managed the Valley landscape (Treutlein and Fages 1972, Crespí and Bolton 1927). As Europeans arrived in the late 18th century, residents of Mission San José began using the Valley to pasture cattle, and grazing persisted as the dominant land use for decades. In the mid-19th century, waves of early immigrants returning from the Gold Rush settled in the Valley, and began dryland farming of grains. Limited acreage of orchards and row crops was introduced in the late 1800s, but grain production continued to dominate across most of the Valley as late as the 1940s (Grossinger et al. 2008, Stanford et al. 2013).

As the population increased in Dublin, Livermore, and Pleasanton in the early- to mid-1900s, dryland grain farming was largely replaced by residential subdivisions and office parks. Demand for reliable drinking water and flood protection increased over a fairly short time span in the mid-20th century (Figure 1.2). Zone 7 Water Agency was founded in 1957 in order to place under local control, through a locally elected board of directors, the vital matters of flood protection and water resource management in eastern Alameda County. With a service area of 1100 km^2 (425 mi^2), Zone 7 is charged with supplying potable water to residents of the cities of Dublin, Pleasanton, and Livermore, as well as roughly 1.21 hectares (3,500 acres) of farmland. In addition, Zone 7 is responsible for providing flood protection for Livermore-Amador Valley residents, and it has largely succeeded in abating the flooding which was common place prior to the 1960s. Today Zone 7 maintains 37 miles (60 km) of channels that receive and convey urban drainage, runoff, and eroded sediment from the tri-cities and the surrounding watersheds.

As shown in Figure 1.2, urbanization has resulted in a substantial increase in the area covered by impervious surfaces (roads, buildings, parking lots, etc.) within the Valley. Within our study area (shown in Figure 1.2, within the historical ecology study boundary, and focusing on the Valley floor portions of Arroyo Mocho and Arroyo Las Positas), the areal extent of impervious surfaces (as determined by aerial photo interpretation and USGS mapping) increased from 848 acres in 1940 (3.3% total land cover) to 10,496 acres in 2009 (41.46% total land cover) (Table 1.1). Urbanization, and the corresponding increase in impervious surfaces, has well-documented impacts on the hydrology, geomorphology and ecology of stream systems, including increased erosion, increased sediment transport, decreased fish habitat, increased risk of flooding, and decreased groundwater recharge (see Dunne and Leopold 1978, Booth 1990, Kondolf and Larson 1995, Everard 2012).

Agricultural and urban development has also resulted in the loss of riparian habitat within Livermore Valley. Along the valley-bottom reaches of Arroyo Mocho, for example, most of the riparian corridor historically was between 60-200 meters (197 to 656 feet) wide, and in some areas extended as wide as 400 meters (over 1,300 feet). Today, 77% of the riparian corridor is less than 60 meters (197 feet) wide (Figure 1.3). In many places the riparian vegetation that exists today is also much denser, though narrower than what existed historically, and is composed of a different suite of species, including non-native species such as eucalyptus.

In recent decades, the populations of Dublin, Livermore and Pleasanton have more than doubled from a total of 99,000 in 1980 to 197,000 in 2010 (US Census Bureau 2010), and remaining agriculture in the Valley has shifting from non-irrigated rangeland to irrigated and controlled drainage viticulture. As a result, water quantity and sediment flux have been altered considerably. Erosion and sedimentation are major problems in different parts of the Arroyo Mocho and Arroyo Las Positas watersheds. In order to maintain channel flood capacity, the City of Livermore has conducted periodic channel de-silting of aggraded areas near several bridges. Periodic desilting is conducted on an as-needed basis by Zone 7 and the City of Livermore and studies are underway to better define the sediment transport and depositional processes. This report highlights some of the causes of these management challenges and suggests potential approaches to both sediment management and habitat enhancement.

Table 1.1. Acres of impervious surface within study area.

Year	Acres of impervious surface	Percentage of study area
1800	0	0%
1940s	848	3%
1980s	6,335	25%
2009	10,496	41%

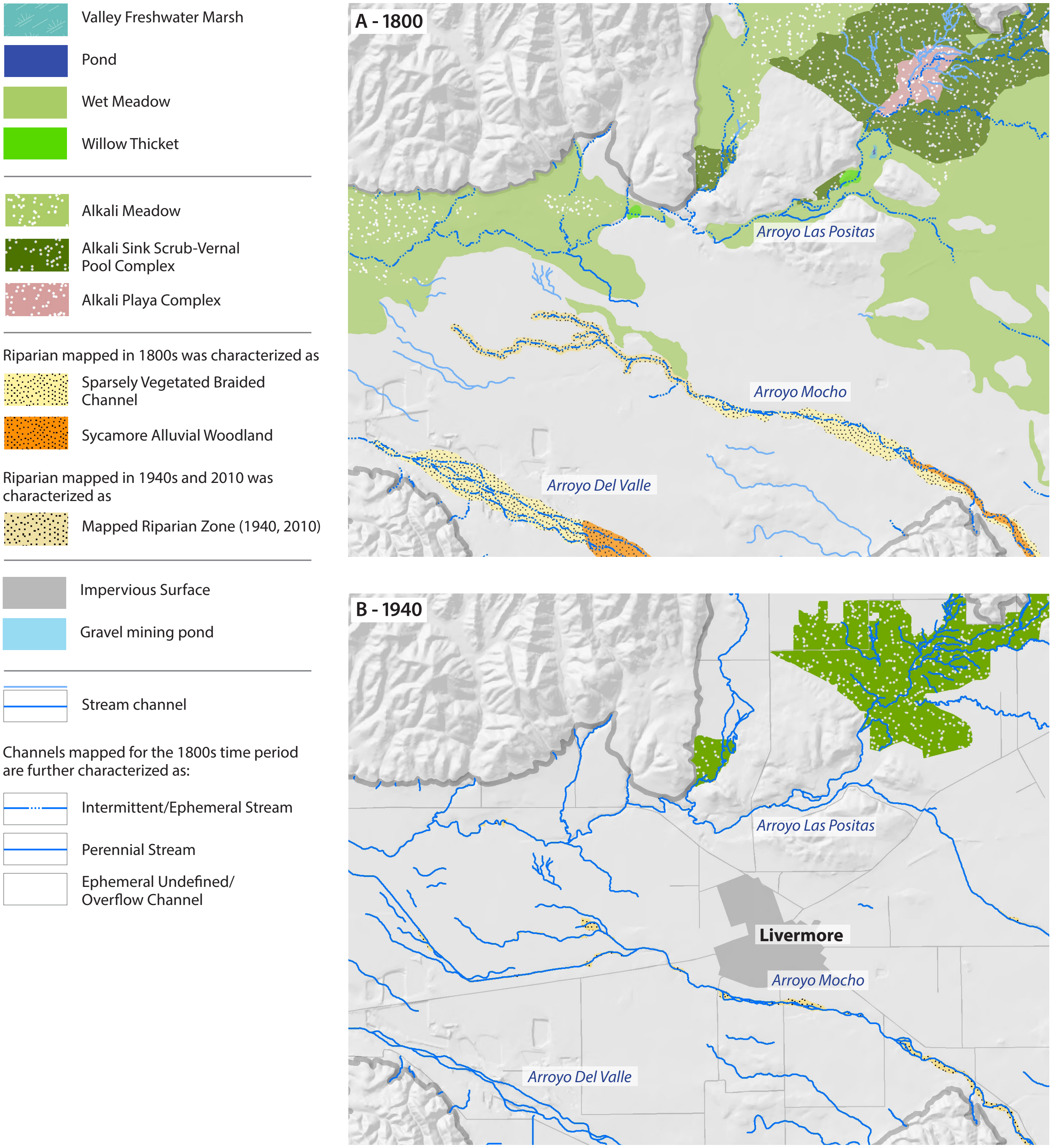
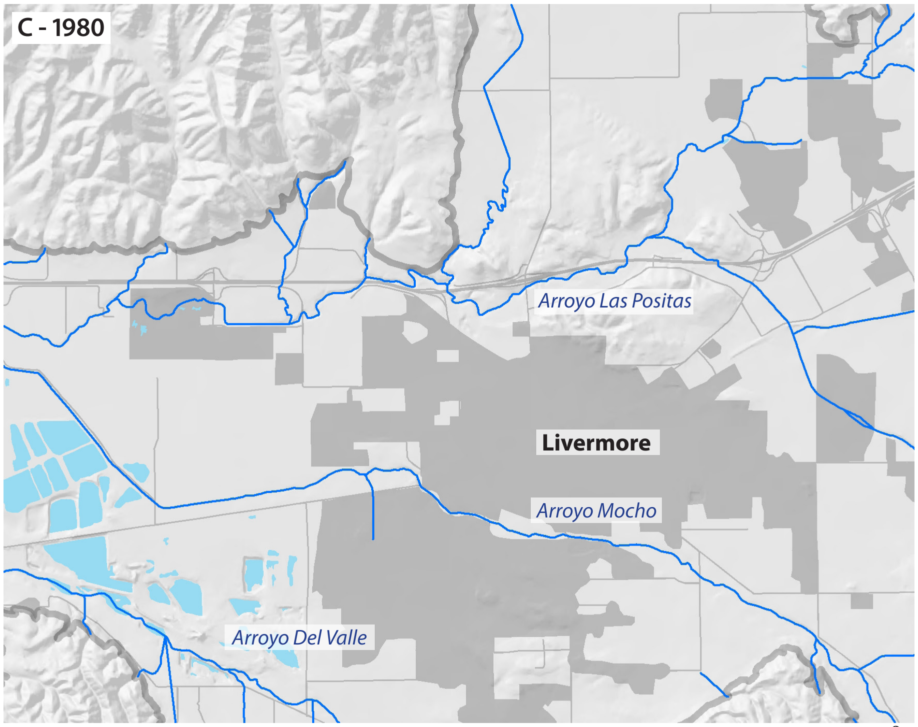
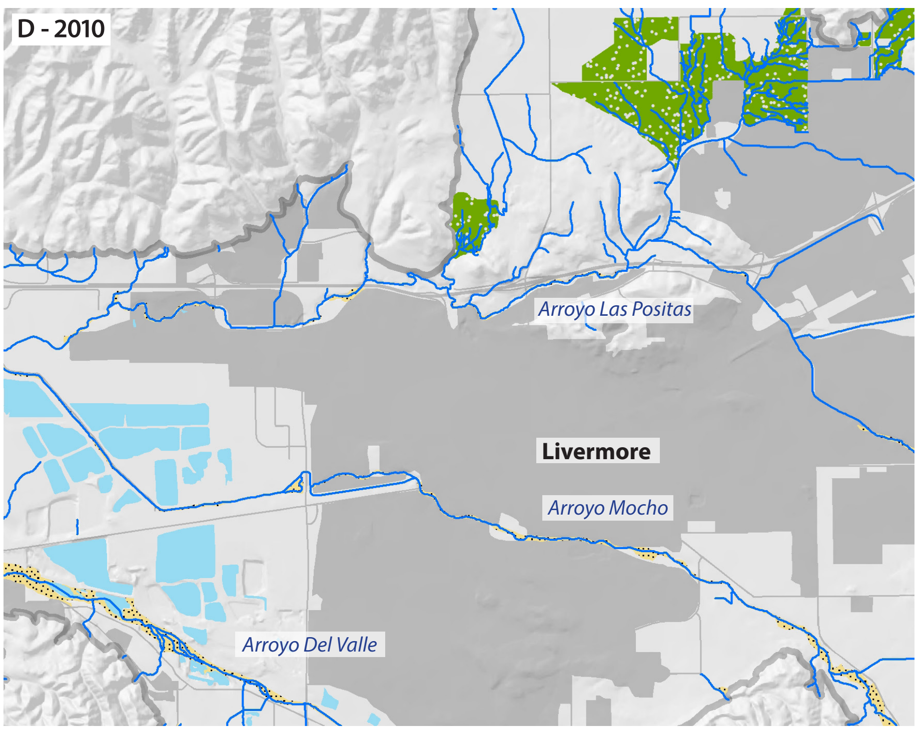


Figure 1.2. Change over time of wetland and riparian habitat, stream configurations, gravel mining locations and general extent of urban development (impervious surfaces) between 1800, 1940, 1980 and ca. 2010. A. Historical conditions representing ca. 1800 (Stanford et al. 2013). B. Conditions in 1940 (USDA 1940, USGS 1940, 1942). C. Conditions in 1980 (USGS 1980, 1981, USGS 2005). D. Conditions in 2010 (USDA 2009, ICF International 2010, SFEI 2011).



NOTE: CHANNELS ARE MAPPED IN LESS DETAIL FOR 1980



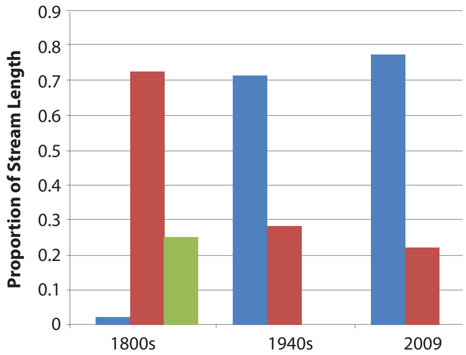


Figure 1.3. Change in riparian corridor width along Arroyo Mocho over time. In the historical period the majority of riparian areas measured between 60 and 200 m in width, with 25% of the corridor over 200 m wide. In 2009, over 75% of the riparian corridor is less than 60 m wide.

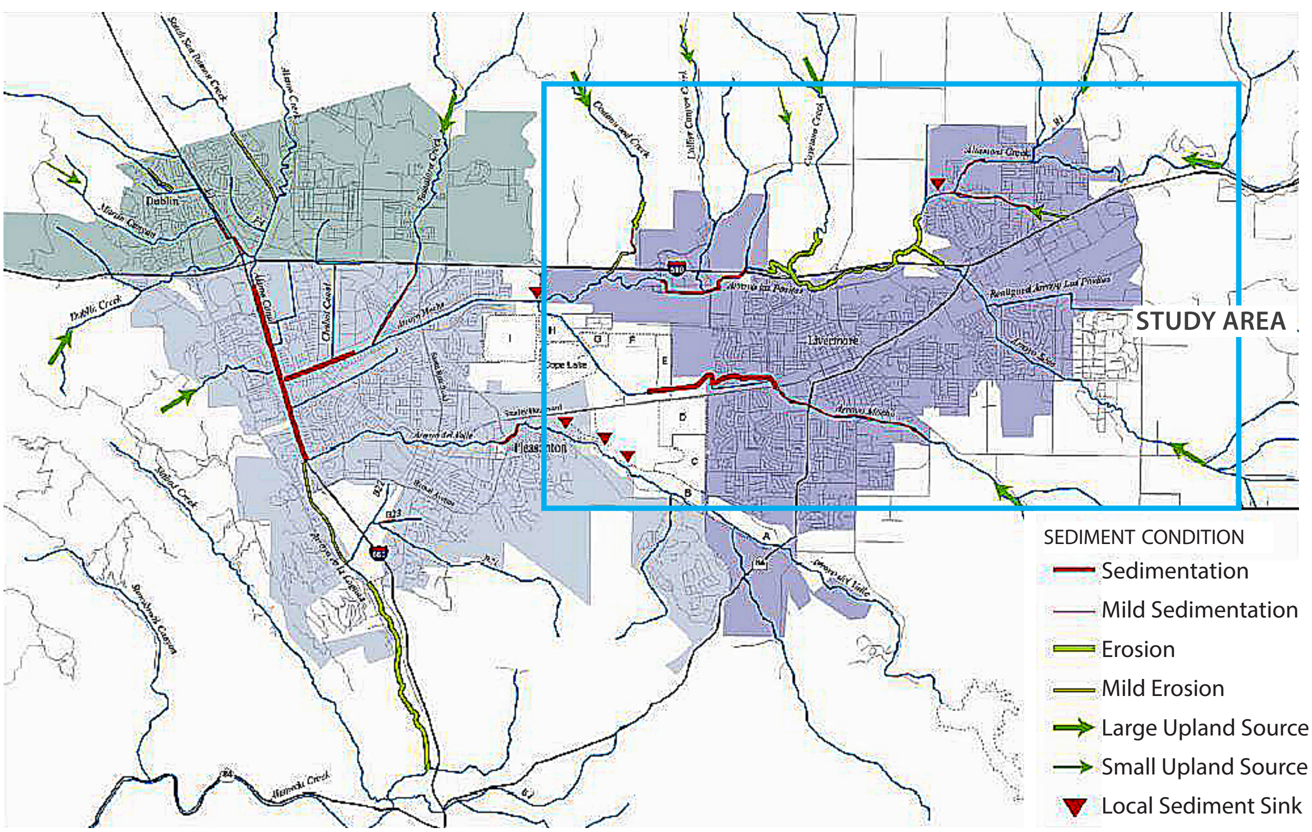


Figure 1.4. Sediment Conditions in Zone 7 jurisdiction as identified by the SMMP. Both erosion and sedimentation occur frequently in the study area (outlined in blue). Our case studies (Chapters 3 and 4) focus in part on these key problem areas.

2. LANDSCAPE EVOLUTION: NATURAL PROCESSES AND HUMAN EFFECTS IN THE LIVERMORE-AMADOR VALLEY

Identifying both the causes of and potential solutions to watershed management challenges first requires the development of a historical landscape perspective incorporating ecological, hydrologic and geologic processes. Many of the problems we face may be longer term geologic and geomorphic responses to climate, tectonics and landscape evolution, which have been both exacerbated or potentially masked by anthropogenic influences. In this section we detail the geologic and geomorphic history of Livermore-Amador Valley and of Arroyo Las Positas and Arroyo Mocho. We then discuss the evolving riparian vegetation, groundwater, and wetland features and patterns in that context (Figure 2.1).

Geology

The Livermore-Amador Valley is an east-west down-dropped depression between the Diablo Range and the East Bay hills (Howard 1979, Carpenter et al. 1984, Sloan 2006). The shape of the alluvial Livermore-Amador Valley floor has changed over time in response to tectonic activity and paleo-fluvial processes, which altered the depositional patterns across the valley floor. Researchers suggest that Pliocene-age uplift of the Diablo Range created alluvial fan deposits along the edges of the Livermore-Amador Valley (Carpenter et al. 1984). Concurrently Arroyo Mocho, the largest stream in the Valley during the Pliocene, deposited Livermore Gravels in a north-west trending direction and finer sediment along the northern edge of the Valley (Figuers and Ehman 2004). To the west, the Valley is bounded by the East Bay hills and flanked by the Hayward and Calaveras faults; to the east, the Valley is bounded by the Altamont Hills and the Greenville Fault; and to the north and south, the Valley is bounded by the Diablo Range. A number of smaller faults cross the Valley, interrupting the flow of groundwater and creating springs. (For more complete discussion see Stanford et al. 2013.)

Because it was created by geological processes rather than carved by streams, the Valley is oversized for its fluvial inputs, allowing streams space to spread and sink. Underlying the Valley are Sierran deposits carried from the volcanically active mountain ranges in the late Pliocene (Ferriz 2001, Sloan 2006). These deposits consists of layers of silt and clay alternating with gravels (Williams 1912, Fisher et al. 1966, Sowers 2003, Sloan 2006). The Valley formed when the surrounding hills began to lift between 6 and 2.5 million years ago (Ferriz 2001, Sloan 2006). The drainages created by this continued uplift contributed sediment, known as the Livermore Gravels, which resulted in deposits up to 4,000 feet thick in places (Howard

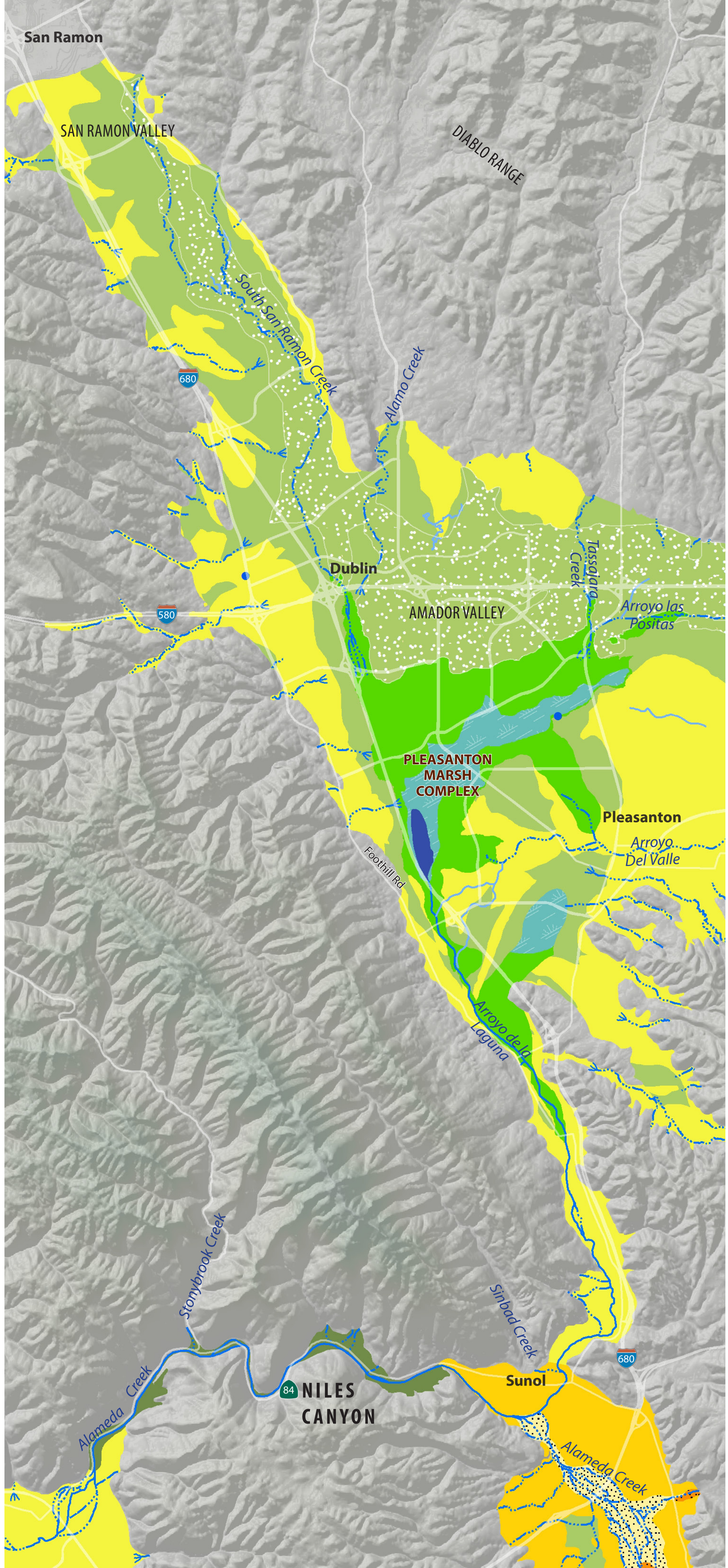
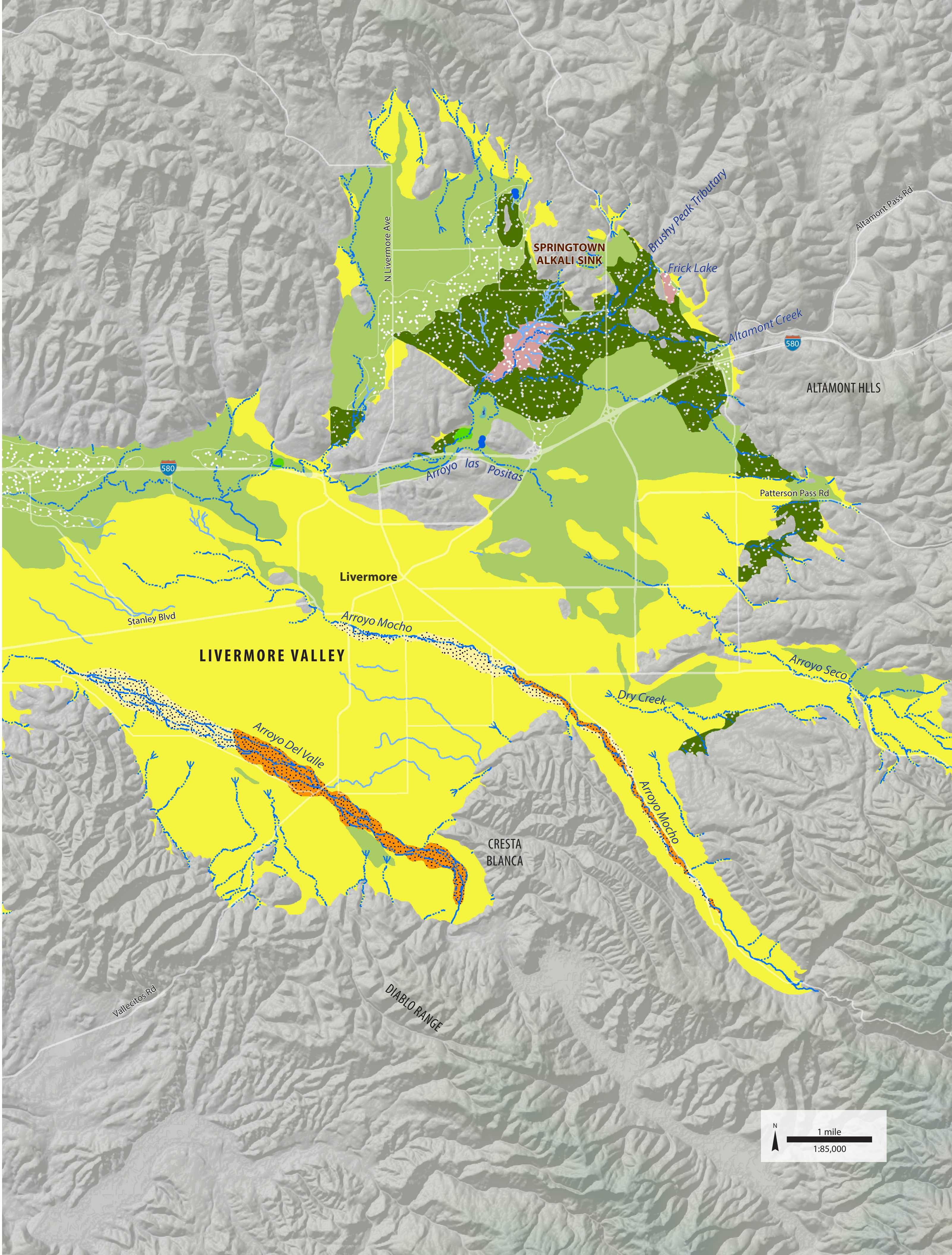


Figure 2.1. Livermore-Amador Valley ca. 1800. Patterns across Livermore-Amador Valley varied from north to south and from east to west. The two wetland complexes—Pleasanton marsh complex in the west and Springtown alkali sink in the east—were prominent historical features. (Stanford et al. 2013)



SPRINGTOWN
ALKALI SINK
Brushy Peak Tributary
Frick Lake
Altamont Creek
Altamont Pass Rd
580
ALTAMONT HLLS
N Livermore Ave
Arroyo las Positas
Patterson Pass Rd
Livermore
Stanley Blvd
Arroyo Mocho
LIVERMORE VALLEY
Arroyo Seco
Dry Creek
Arroyo Del Valle
CRESTA
BLANCA
Vallecitos Rd
DIABLO RANGE
N
1 mile
1:85,000

1979, Sloan 2006). Over the millennia watercourses shifted, alternately flowing north through San Ramon Valley and south through Sunol (Williams 1912, Ferriz 2001). At times the San Ramon Valley route was blocked, allowing sediment to settle in the low points of the Valley and resulting in the deposition of layers of silt and clay (Williams 1912, Ferriz 2001, Sloan 2006).

In the 1800s, two broad braided creeks, Arroyo Del Valle and Arroyo Mocho, drained from the Diablo range into the southern portion of the Valley. A series of smaller creeks with narrower channels – most notably Arroyo Las Positas – also drained into the Valley, particularly from the north and east. Most sediment was produced in the upper watersheds of Arroyo Mocho and Arroyo Del Valle. The geology of the surrounding hills influenced sediment types and patterns of deposition and storage through the watershed. The headwaters of Arroyo Mocho, Arroyo Del Valle, and Alameda Creek flowed from the high sediment-producing steep hillslopes of the Franciscan formation, resulting in a comparatively coarse bedload in these streams, and a comparatively high sediment yield. Coarse sediment entered the Valley primarily in pulses during flood events, and from large mass wasting events. Smaller drainages in northern Livermore-Amador Valley, such as Arroyo Las Positas, derive from the less erosive Great Valley Sequence, resulting in a finer sediment load and less stream power overall (Figure 2.2). Two major wetland complexes existed in the historical period (ca. 1800s): the Pleasanton marsh in the western part of the Valley, where perennial water was available, and the Springtown sink in the eastern part of the Valley, where intermittent flow created high alkali concentrations and vernal pool complexes. These wetlands naturally acted as fine sediment sinks, off channel habitat, and detention basins under high flow conditions (Figure 2.3).

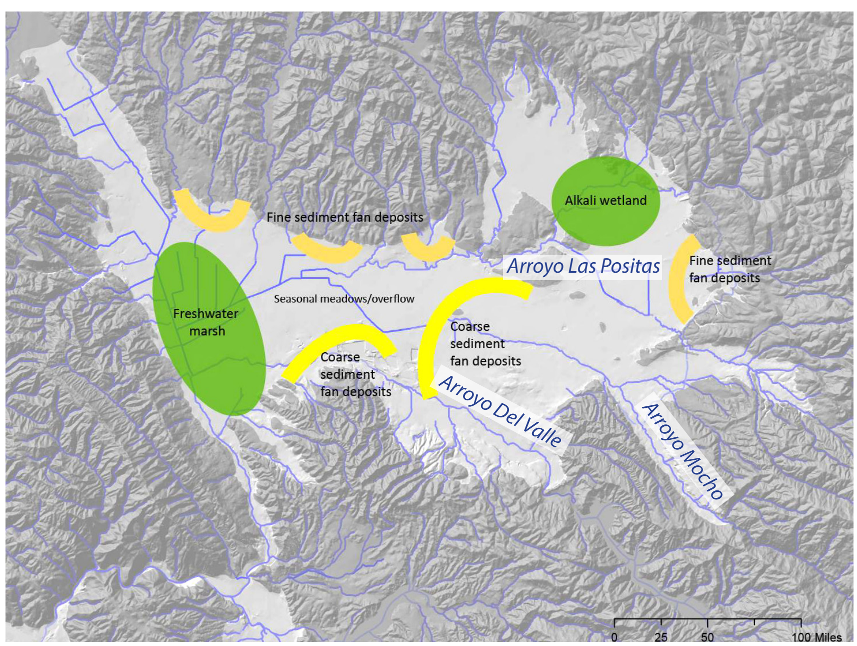


Figure 2.2. Conceptual depiction of the arrangement of alluvial fan deposits and wetlands in Livermore-Amador Valley. These fan deposits would have changed in size and dominance over time, but the imprints of their most recent forms are still visible in the topography of the Valley.

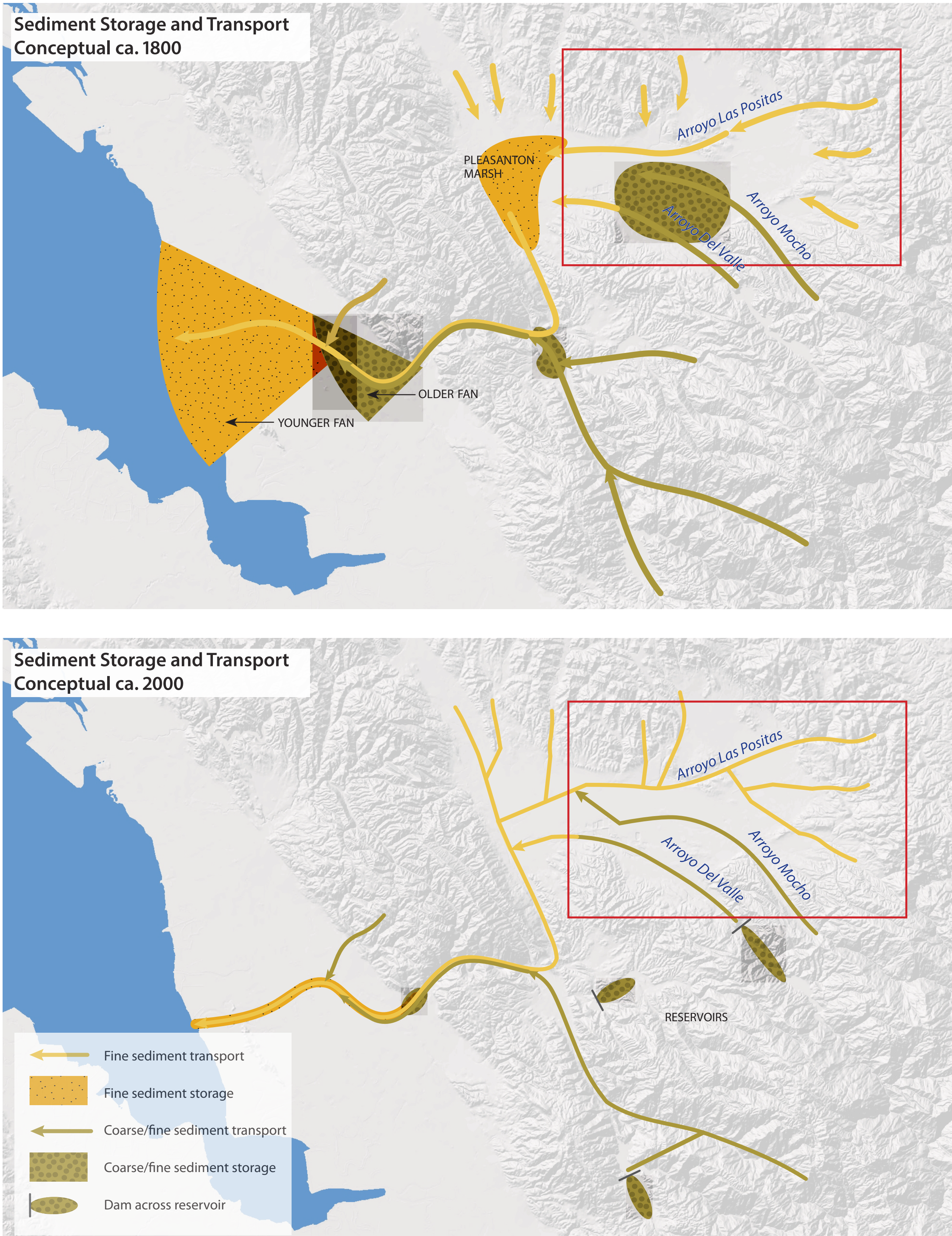


Figure 2.3. Conceptual depiction of sediment storage and transport. These diagrams show changes in dominant sediment deposition patterns that the watershed has accommodated (study area outlined in red). Rather than spreading sediment broadly across their floodplains, streams now often store sediment within their lower channels, resulting in aggradation and the need for active management. Much of the coarse sediment supply to the valley floor that occurred historically is now being trapped behind reservoirs. Almost all reaches transport both fine and coarse sediment—this diagram attempts to show which is dominant. Coarse sediment is defined as >2mm.

Currently, both the natural and constructed channels within the Zone 7 service area experience erosional and depositional changes annually. Upstream erosional processes (both episodic and chronic), channel incision, and bank failures have increased downstream aggradation, exacerbating management challenges related to flow and sediment. The watershed has also experienced changes in sediment supply, largely related to changes in land use. Historically, the dominant supply of coarse sediment came from the upper watersheds, which created the alluvial fans of Arroyo Mocho and Arroyo Del Valle (Figure 2.2). Today, the Arroyo Mocho sub-basin contributes over 40% of the sediment yield to Livermore-Amador Valley. Arroyo Seco, Altamont creek and Cayetano creek, all tributaries of Arroyo Las Positas, each contribute between 10-15% of the total load to the Valley (Bigelow et al. 2012). Periodic landslides and debris flows, channel incision and widening, and stream bank failures, likely account for the major sources of sediment flux (Bigelow et al. 2008, Pearce et al. 2009, Beagle et al. 2011, Beagle et al. 2012, Bigelow et al. 2012).

Riparian vegetation

Variations in channel morphology and dry season flow patterns historically resulted in a wide diversity of riparian vegetation types in the Livermore-Amador Valley. Different stream reaches exhibited distinct patterns in both riparian width and species composition. Stanford et al. (2013) mapped willow-cottonwood forest and willow thickets along reaches with high groundwater such as Arroyo de la Laguna and the Pleasanton marsh complex; sycamore alluvial woodland in the broad, braided, intermittent reaches of Arroyo Mocho, and Arroyo Del Valle; herbaceous cover with sparse oaks and sycamores along small drainages with low flow (lower Mocho and Del Valle, Arroyo Las Positas, and small tributaries); and alkali sink scrub through the alkali reaches of Springtown. Within the study area historically, stream corridor width (from one edge of the riparian vegetation across the stream to the other edge) varied from extremely narrow borders of herbaceous riparian vegetation with occasional oak trees, to over 800 feet (244 m) through the broad braided reaches of Arroyo Mocho (Figure 2.4).

Along most stream reaches riparian vegetation has been narrowed and floodplains have been eliminated to make more space for housing, agriculture, and roads. Long stretches of riparian habitat have been removed to make way for agricultural and urban development, and aggregate mining. Other changes are less obvious. Many of the riparian communities best adapted to xeric conditions—sycamore alluvial woodland and sparse oaks—have been converted to wetter types because of more managed perennial flows resulting in low flow, willow-lined channels. The wide reaches have largely been eliminated; in other cases, even if the riparian corridor width persists, streams have often been disconnected from their floodplains. There are also some notable remnants of historical riparian cover, such as the sycamore alluvial woodlands in southeastern Livermore Valley (Figure 2.4). The historical habitat patterns represent

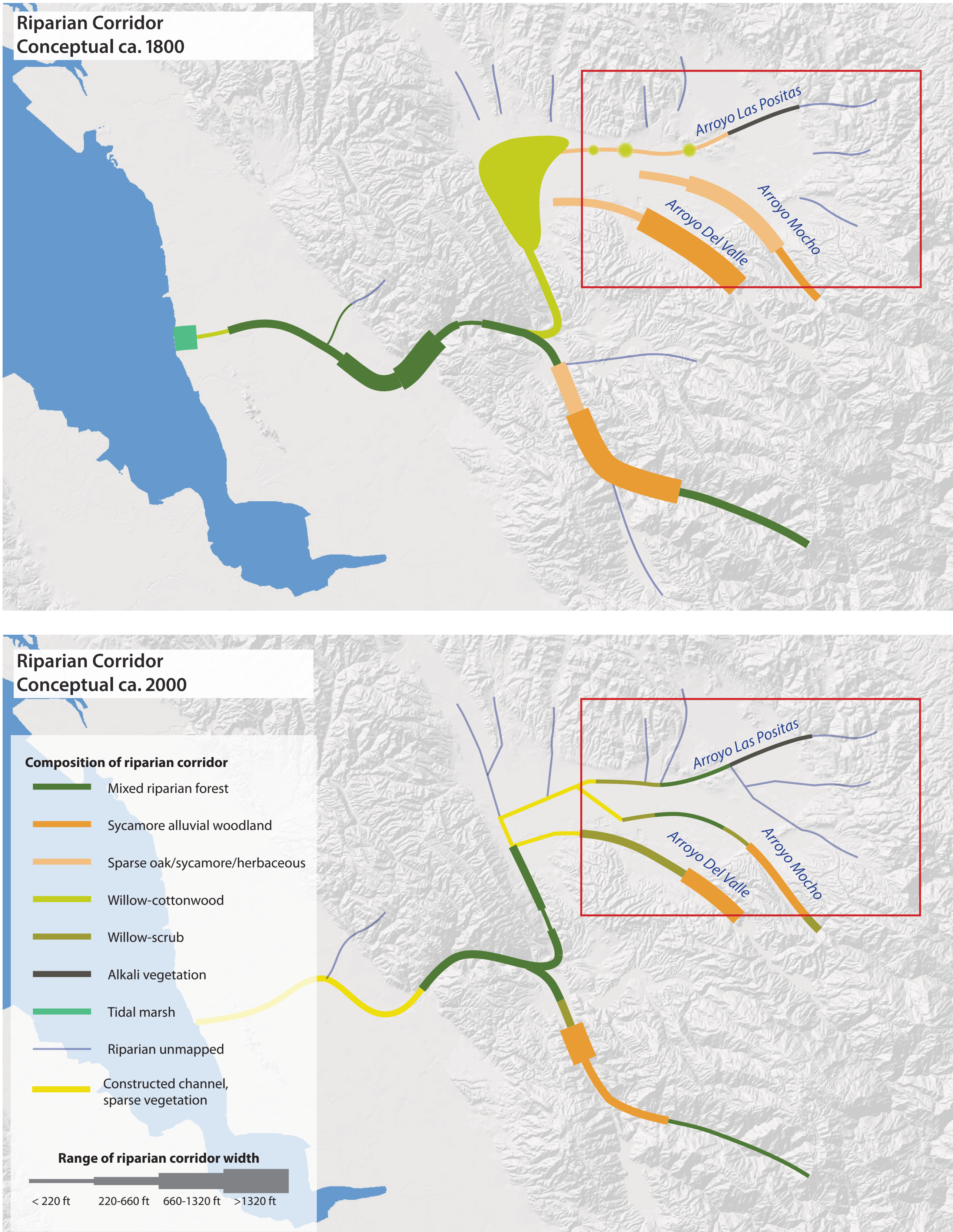


Figure 2.4. Conceptual depiction of riparian cover. The diversity of riparian widths and types has been greatly simplified, reducing the diversity of ecological functions in the Alameda Creek watershed. In particular, the broad willow forests and floodplains are no longer present. Widths have narrowed—if we consider the Pleasanton marsh complex a riparian habitat type, the riparian corridor extended 4,000 feet wide in places. Species composition has also shifted—today, mixed riparian forest may include exotic species such as eucalyptus. In the contemporary diagram we introduced two additional classes to represent willow scrub and the sparse vegetation along flood control channels, neither of which were present historically. The study area is outlined in red.

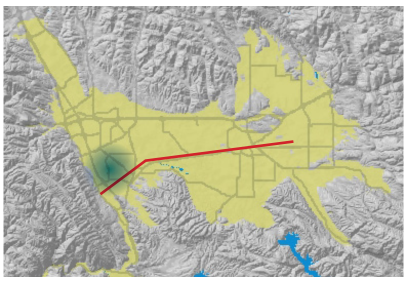
a diverse palette to draw upon as we attempt to re-establish riparian biodiversity in contemporary stream settings.

Groundwater

A large groundwater basin lies beneath the Livermore-Amador Valley, containing multiple distinct aquifers and aquitards (clay layers separating aquifers). Historically, groundwater recharge occurred where water flowed over permeable substrates such as the coarse gravels of the alluvial valleys and fans of southeastern Livermore Valley. The groundwater basin supported numerous surface water features, including artesian springs and wetlands. The large wetland systems in the Valley – the Springtown alkali sink and the Pleasanton marsh complex (see Wetlands on p. 17) – occurred where poorly drained clay soils precluded groundwater recharge and where faults, bedrock barriers, and topography forced groundwater to the surface (Lee 1916). Figure 2.5 shows a cross section of historical water levels over time (including the surface water in 1899 at Pleasanton marsh).

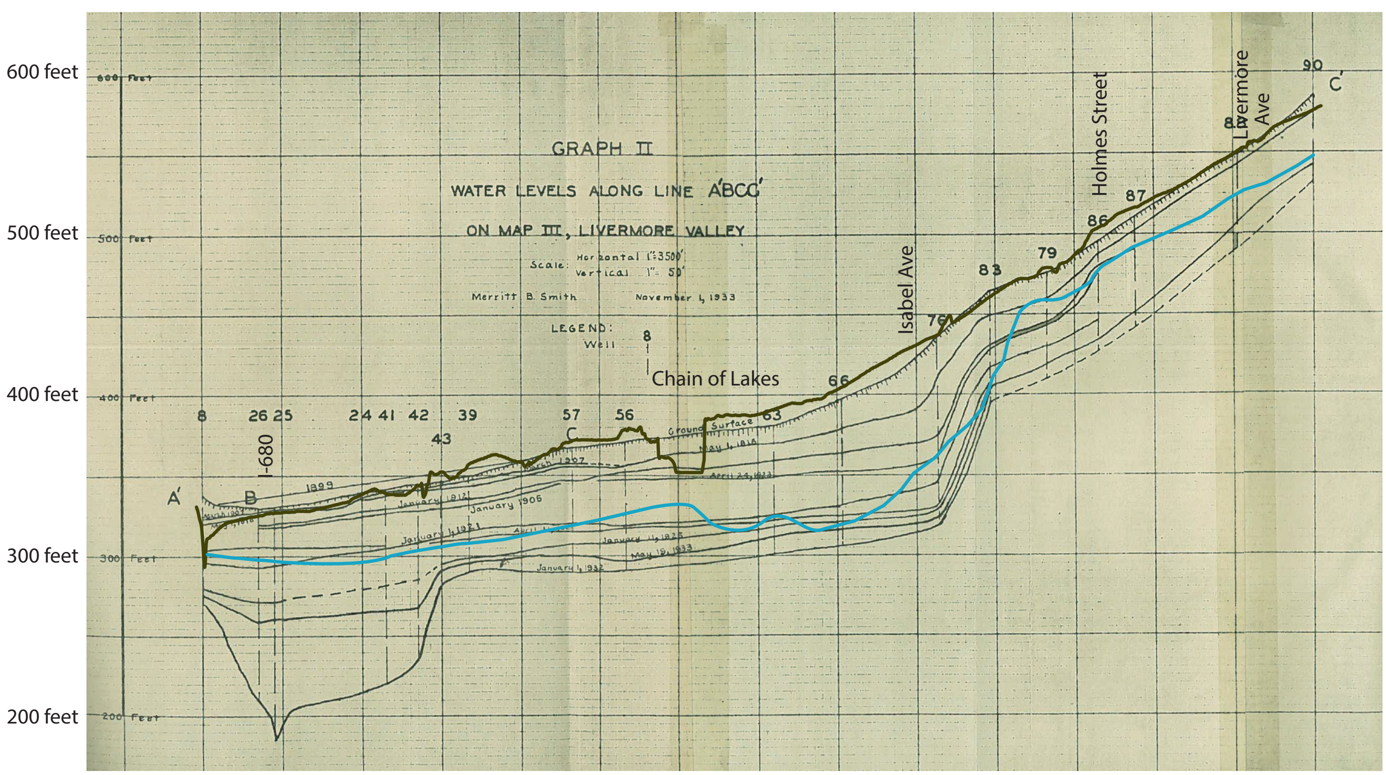
Extensive groundwater withdrawal in the early 1900s, combined with a decades-long drought, contributed to the drying of Pleasanton marsh and other wetlands. For instance, in 1907 groundwater levels just south of Pleasanton marsh were still several feet below the ground surface. By 1921, water levels had dropped to approximately 35 feet below the surface, and by 1932 groundwater levels had dropped to nearly 120 feet below the surface (Figure 2.5; Smith 1934). In some areas, groundwater levels fell by over 10 feet in a single year (Smith 1934). Groundwater from the Bernal sub-basin continued to be used as a water source for the San Francisco

Figure 2.5. Cross section comparing historical and contemporary groundwater levels. This cross section, extending from the city of Livermore, through the Chain of Lakes to the outlet of the Valley at Arroyo de la Laguna, documents the rise and fall of shallow groundwater elevation over time including levels from 2010 (Smith 1934, Zone 7 2010). The approximate location of the cross section and the Pleasanton Marsh complex are shown on the locator map.



Ground surface (Sanborn Mapping 2007)

Groundwater surface (shallow) – Fall 2010 (Zone 7 2010)



Public Utilities Commission (SFPUC) through the 1940s, when low water levels caused pumping to be reduced (Fisher et al. 1966, CA Department of Transportation 1998).

Today, recharge through abandoned quarry ponds and releases of State Water Project water through Arroyo Mocho and Arroyo Del Valle help to maintain groundwater levels (DWR 2006). Groundwater is pumped for water supply for the Valley, and water levels are closely monitored to ensure that they do not interfere with mining in the remaining quarries. Modern groundwater levels are still lower than pre-hydromodification levels, but they are substantially higher than they were in the early 1900s.

Wetlands

In the mid-1800s, the Valley contained an estimated 19,600 acres of seasonal wetlands, with an additional 650 acres of perennial wetlands and 2,000 acres of willow thicket or swamp. The two largest wetlands were the Pleasanton marsh complex on the western side of the Valley, and the Springtown alkali sink on the northeastern side of the Valley. Wetlands also dominated much of the northern and western sides of the Valley, stretching from east to west in a nearly continuous swath (see Figure 2.1). Variation in rainfall both seasonally and interannually created substantial spatial variation in the extent of wetlands: in the winter, much of the Valley would have been saturated, while in summer the seasonal wetlands dried to hard, grassy land. Today only 1,220 acres of wetlands remain – 800 acres of alkali seasonal wetland, mostly in Springtown, as well as 400 acres of freshwater seasonal wetland and 20 acres of perennial freshwater marsh (ICF International 2010).

Pleasanton marsh complex

The Pleasanton marsh complex, an important component to the functioning of the Valley historically (though not in the study area for this particular document), spread across about 2,600 acres at the western edge of Livermore-Amador Valley (or 10,000 acres including the surrounding seasonal wetlands). This wetland extended from Interstate 580 on the north to the intersection of Sunol Boulevard with Interstate 680 on the south, and from Foothill Boulevard east beyond Santa Rita Road, covering much of modern-day Pleasanton (Figure 2.6). The location and character of the Pleasanton marsh complex were controlled by the geology and hydrology of the Valley. The alluvial fans of Arroyo Mocho and Arroyo Del Valle confined the marsh on the eastern side, while the East Bay hills and Vallecitos Valley bounded the marsh to the west and south.

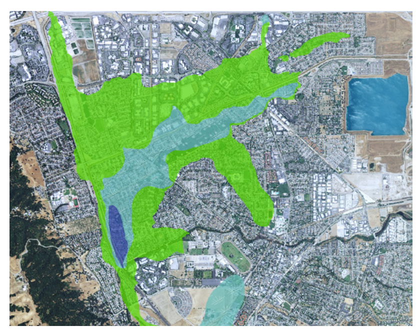


Figure. 2.6. Historical extent of the Pleasanton marsh overlaid on modern aerial imagery. This graphic shows the three main habitat types that made up the Pleasanton marsh: a perennial pond (dark blue), freshwater marsh (light blue), and willow thickets extending into seasonally inundated wetlands (green). At its most inundated, the marsh would have covered much of modern day Pleasanton.

In the center of the marsh complex, a perennial pond occupied the lowest portion of the Valley and was drained directly by Arroyo de la Laguna to the south (LaCroze 1860, Whitney 1873, Allardt 1874, Allardt [1880]1907, Edwards 1932, California Legislature Assembly 1854:54, Gutmann 1919:25). The pond grew and shrank based on rainfall and groundwater

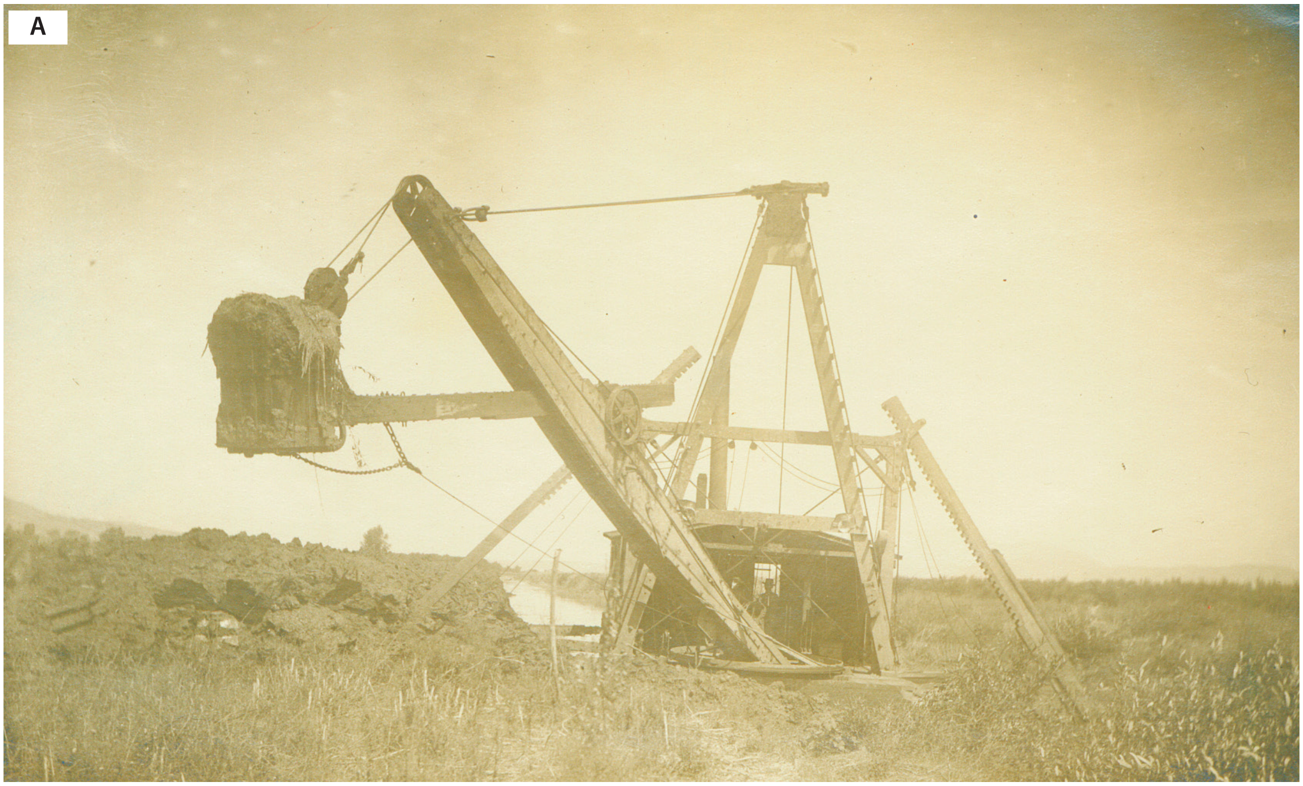


Figure 2.7. Ditching and draining of channels in Livermore-Amador Valley. These images show A. A dredger in action on Arroyo de la Laguna in the early 20th century, and B. The impacts of dredging as seen on the channel banks (Von Geldern 1907). This type of dredging and consequent impacts were widespread in the Livermore-Amador Valley from the 1880s onward into the 20th century.

A

B

Figure 2.8. Photos of flooded Pleasanton valley in 1907. A. photograph from April 4, 1907, looking south from the bridge over the Chabot Canal. The caption on the original photograph reads, "Old Lake Pleasanton on the left, water two feet deep." B. Photograph from April 4, 1907 looking east along the levee of Chabot Canal from the same bridge (Von Geldern 1907). Flood waters frequently re-occupied the low lying areas of the "Old Lake Pleasanton" until the 1950s.

levels. Surrounding this pond was a swath of valley freshwater marsh, dominated by tules (*Schoenoplectus* spp.), yet the marsh would have included a suite of other freshwater emergent species, including rushes (*Juncus* spp.) and sedges (*Carex* spp.). Further removed, the willow thickets around the border of the perennial wetland occupied areas inundated for shorter periods (Howe 1851, Allardt [1880]1907, La Croze 1860, Duerr 1872, Cash 1875). While the center of the marsh was perennially saturated, the extent of open water within the rest of the marsh complex varied seasonally and interannually. In the wet season, open water likely extended across the marsh and into the wet and alkali meadows to the north, contracting in late summer.

From as early as the 1880s, the Pleasanton marsh began to be ditched, drained and developed (Figure 2.7). Yet, despite this rapid conversion, the wetland did not entirely disappear. Into the 20th century, the drainage canals initially "would easily silt up and overflow with tule and weeds and the property would be flooded nearly every year" (Gutmann 1919). Photos give an adequate idea of the expanse of water that would collect in the location of the marsh long after the initial ditching and draining efforts (Figure 2.8; von Geldern 1907:63).

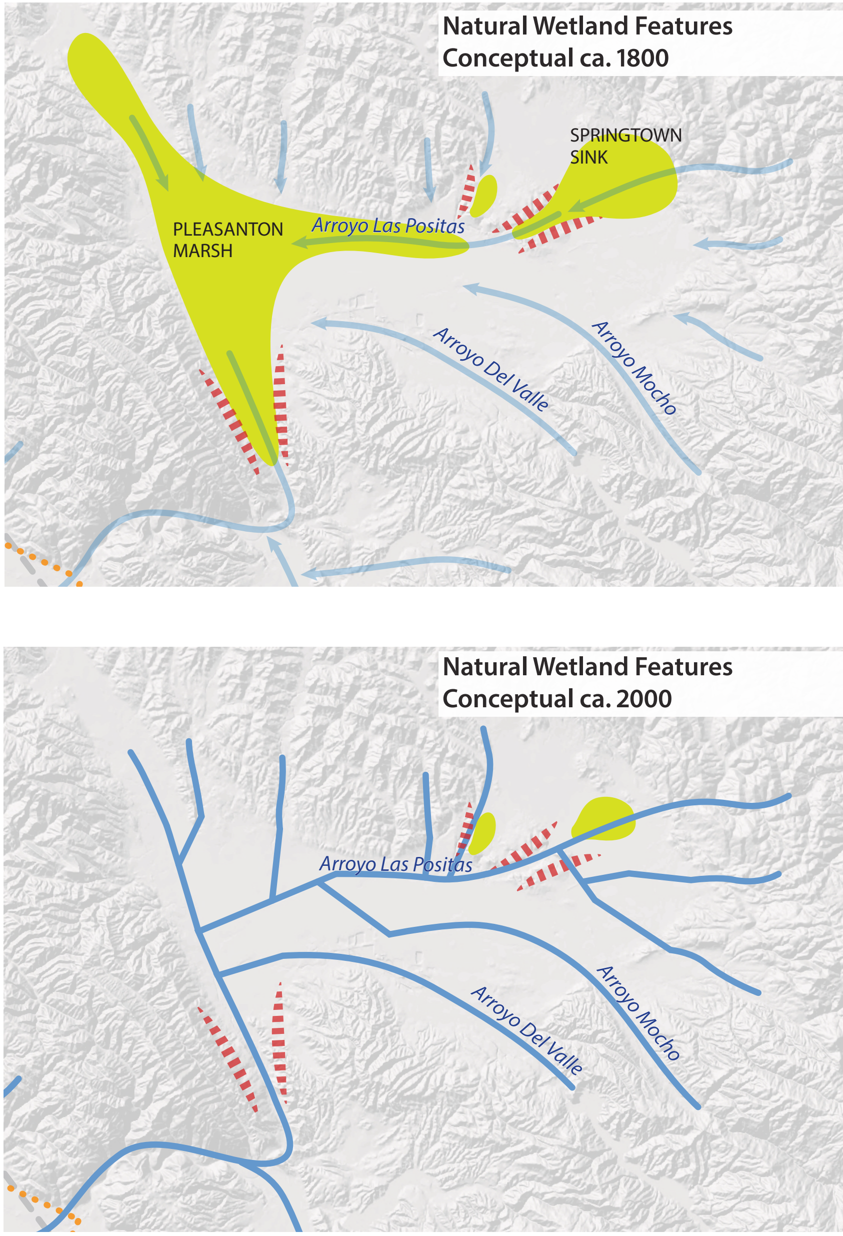
Early engineers recognized the impact of draining the marsh on the watershed: "The sinks communicate with the creeks, and the creeks with the canals, and the result of this arrangement in the beginning of the wet season will be that the first rains are led more rapidly to the valley's main outlet," (von Geldern 1907:65). Diking of the marsh reduced surface storage and sediment deposition, and directed water more rapidly through Arroyo de la Laguna, through Niles canyons and into lower Alameda Creek. After this diking, severe incision was observed on Arroyo de la Laguna and downstream.

Springtown alkali sink

The Springtown alkali sink was a large alkali wetland east of Livermore. Significant portions of the alkali wetland still exist, though its extent has been greatly reduced. The Springtown alkali sink contained a variety of alkali wetland types, including alkali playa, alkali sink scrub, vernal pool complex, and alkali meadow. See page 48-49 for more in-depth discussion of the sink's habitats and ecological functions.

Influences of topography and climate

Topography as well as climate influenced wetland distribution in Livermore-Amador Valley. Bedrock exposures protrude above the valley floor at two significant points in the study area. These hills interrupt the flow of ground- and surface-water, creating poorly-drained areas, which facilitated the development of wetlands. East of Livermore, the



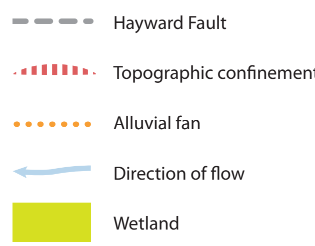


Figure 2.9. Conceptual depiction of wetland forcing features. This diagram shows how landscape-level patterns of topography and soils determine where wetlands occur—and where they do not. The well drained upper fans of Arroyo Mocho, Arroyo Del Valle, and Alameda Creek precluded the formation and maintenance of wetlands across much of the study area, instead facilitating groundwater recharge. Wetland mosaics formed in the poorly drained distal ends of fans. These processes combined with natural bedrock barriers to create the watershed's most important wetland complexes at Pleasanton and Springtown. Today most large natural wetlands are remnants of these former features, maintained by many of the same processes. Another small alkali area still exists in an undeveloped area near Cayetano Creek.

Springtown alkali sink was located behind the knolls of the Springtown anticlines, formed by late Quaternary uplift (Sawyer 1999) and supported seasonal alkali wetlands with low scrub and herbaceous vegetation (Figure 2.9). The basin west of Pleasanton, confined by the East Bay hills and by alluvial fans formed in the Pliocene, developed into the Pleasanton marsh complex containing many springs and supporting a large area of open water, seasonal wetlands, and extensive willow thickets and freshwater marshlands. The Pleasanton marsh complex occurred at the lowest point of the Valley, and as a result received more ground and surface water inputs and was more consistently saturated than the Springtown sink. The dry climate gradient of the Valley also shaped vegetation patterns in these wetland areas.

3. ARROYO MOCHO AND ARROYO LAS POSITAS CASE STUDIES: CONNECTING PAST, PRESENT, AND FUTURE

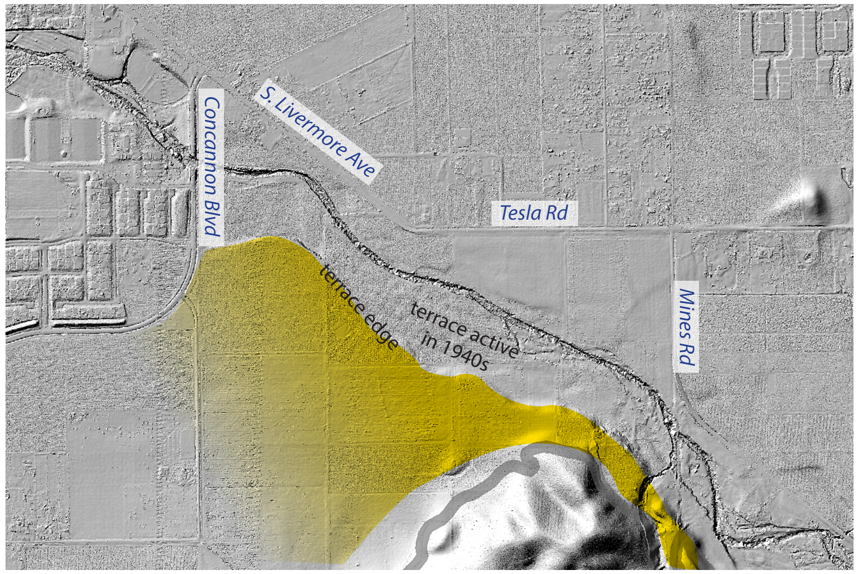
The landscape perspective outlined in the preceding sections sets the foundation for a focused analysis of the management challenges and restoration potential of two stream systems: Arroyo Mocho and Arroyo Las Positas. In the following sections, we explore the underlying physical and ecological processes acting on reaches of these two stream systems during the historical period (ca. 1800). We then explore change over time in certain problem locations identified by the SMMP (Zone 7 2006), using information about historical ecology and physical processes to further understand possibilities for designing with nature into the future. To facilitate analysis at a useful level of detail, this discussion is organized into discrete "case studies" corresponding to short stream reaches, but in reality these reaches are closely interconnected and should be managed holistically within the context of the watershed. Each case study includes a problem statement summarizing current management challenges, a review of underlying physical and ecological processes, an analysis of changes over time, and an assessment of future management and restoration potential. The first three case studies focus on Arroyo Mocho, while the last two focus on Arroyo Las Positas; each set of case studies is prefaced with a brief discussion of pertinent historical ecology background information.

Arroyo Mocho historical ecology background

Morphology and historical sediment supply

Arroyo Mocho drains a 60 square mile (155 km^2) watershed, smaller than its now impounded neighbor Arroyo Del Valle (146 mi^2 (378 km^2) upstream of the dam and 21.6 mi^2 (56 km^2) downstream of the dam). Historically the Arroyo Mocho transitioned from a narrow single-threaded channel through a semi-confined canyon along Mines Road to a broad stream corridor with occasional braiding reaches across its fan, ending in a series of distributaries near Isabel Road and Stanley Blvd. It was described as "narrower and more shifting" than Arroyo Del Valle (Fuller 1912:41). Over time, the active channel of Arroyo Mocho shifted back and forth between these low banks (Fuller 1912:41). One of several detailed General Land Office surveys was made by William Carlton, who crossed the creek twice (once going north and once going south) in April 1874. He described banks 200 feet wide and a "main channel" of Arroyo Mocho six hundred feet wide. He also described ascending a bench 25 feet (7.6 m) high (Carlton 1874). In the 1940 aerial photographs, this bench is still visible, and traces can still be followed in the 2007 LiDAR surveys (Figure 3.1).

As Arroyo Mocho approached the historical town of Livermore (near the current intersection of Holmes Street and Murietta Boulevard), it became more braided. Multiple channels can be seen in aerial photographs from 1940, and in times of flood the creek scoured beyond these channels to banks on either side, depicted in early maps as a substantially broader



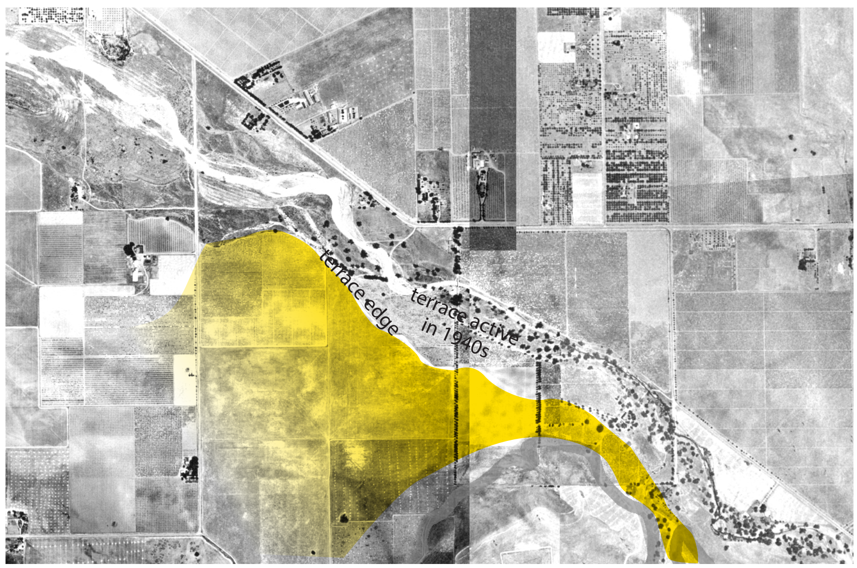


Figure 3.1. Terrace evident in 2007 LiDAR and 1940 imagery. A terrace surface on the south side of Arroyo Mocho is visible in the 2007 LiDAR digital elevation model (the edge of the terrace can be seen in yellow). The terrace is also evident in aerial photography from 1940, when the terrace boundary can be seen at the edge of the cultivated fields. Because Arroyo Mocho has been confined to a single-thread channel, the terrace is no longer active, but the signature of a formerly shifting channel still persists. (USDA 1940, Sanborn Mapping 2007)

reach (Allardt 1874, Thompson and West 1878, USDA 1940). The creek periodically overflowed even these broader banks into the town of Livermore (Williams 1912:305). Gravel mining could exacerbate erosion—"the consequent washing away of the banks and bed of the creek…made the crossing quite dangerous" according to the Echo (1894a). The dynamic and erosive nature of the stream and its proximity to Livermore may explain the more intensive ditching of Arroyo Mocho through this stretch compared with further upstream.

The creek historically occupied a much broader zone than it does today. In the climatic and geomorphic setting of the 19th and early 20th centuries, Arroyo Mocho was an actively aggrading stream due to its high coarse sediment supply and high stream power. The historical record indicates that at least by 1900, Arroyo Mocho was undersized for high flows and frequently flooded across the Valley. Cyril Williams described the undersized creek in 1912: "the channel of the creek is wide and shallow, and in times of ordinary or heavy floods these banks overflow, upon occasion even through the town of Livermore" (Williams 1912:305).

The high discharge and slope, paired with a substantial coarse bedload supply, supported the active braiding and multi-stem form of Arroyo Mocho in this reach. It is possible that in the early Holocene, Arroyo Mocho created an alluvial fan as it spread over the Livermore Valley, and at a certain point, a shift in sediment supply and discharge caused the channel to incise into its fan, leaving behind the large benches and terraces still seen in the LiDAR data. Meanwhile, active braiding continued within the confines of the abandoned terraces or former fan surface. The shifting channels, bars, and bank erosion maintained the shallow and wide channel and the bed slope likely remained high enough to transport the gravels and support braiding (Knighton 1998). As the slope of the channel lessened towards the bottom of the fan, the median gravel size likely decreased as stream power diminished, and the braiding decreased in width and complexity (Knighton 1998).

Flows

Arroyo Mocho maintained perennial surface flow through its confined canyon. As it entered the Valley, flow became intermittent as water slowly sank through the alluvial gravels near the town of Livermore. Towards the top of the alluvial fan, surveyor Sherman Day described a "copious stream running here over a rocky and a gravelly bed" in August 1853 (Day 1853). Further downstream he described pools, adjacent to a reach of stream that was "entirely dry." West of Oak Knoll Cemetery, downstream of the Western Pacific Railroad crossing, Arroyo Mocho crossed a thrust fault (the Livermore Fault), and historically began to bifurcate into distributary channels and to lose its defined channel form (Day 1853, Halley 1876). Although different sources propose different reasons for the name Mocho (translated as "cut-off"), surveyor Sherman Day explained that it was so named "because it terminates about 2 miles W. of Livermore by spreading itself out on the plain" (Day 1853). In times of flood, surface flow continued as sheet flow or through poorly defined and discontinuous channels, but much of the flow sank into the coarse gravels of the Valley.

The stream responded to interannual variability in rainfall and runoff conditions. During wet years, the distributary channels supported a surface water connection to the Pleasanton marsh, providing corridors for migratory species, nutrient exchange, and other ecological functions. In dry years, no surface connection existed between Arroyo Mocho and the rest of the Alameda Creek watershed (Sowers 2003, Stanford et al. 2013). Subsurface flow from Arroyo Mocho seeped towards the Pleasanton marsh complex and Arroyo Las Positas, and was seen as an important groundwater source (Williams 1912). Even today, this creek is used to recharge groundwater. The lack of a defined channel in the lower part of Arroyo Mocho and the unpredictable and varying nature of sheet flow patterns likely motivated early efforts to ditch and redirect the creek, which may have occurred as early as 1878 (Thompson and West 1878).

Riparian vegetation

Arroyo Mocho supported a riparian corridor that varied in width and density, but most likely averaged around 800 feet (244 m) wide in the braided reaches. This zone of creek influence included sycamore alluvial woodland, oaks, and bars and islands, and the creek was flanked by active benches and abandoned terraces. Surveyor Day observed white (valley) oaks in 1853 "on a level clay, flat bench, being at the bottom of the 'Arroyo Mocho', coming out of the mountains" (Day 1853). Scalebroom scrub *(Lepidospartum squamatum)* was also recorded along Arroyo Mocho (Sharsmith 1945). Scalebroom occurs primarily in the Great Basin and deserts and is associated with intermittently flooded alluvial deposits and vegetation types, such as sycamore alluvial woodland and mulefat scrub *(Baccharis salicifolia;* Sharsmith 1945, Magney 1992, Sawyer et al. 2009).

Near Livermore, sycamore alluvial woodland disappeared and tree cover was likely sparser due to the intermittent water supply, but large riparian trees continued. A local historian stated that "the banks [of Arroyo Mocho]… abound with oak and sycamore trees of great size" (Wood 1883). General Land Office (GLO) surveyor Sherman Day crossed Arroyo Mocho just over half a mile west of Oak Knoll, and described a creek 60 feet wide, with "a wide gravel bottom…the creek is lined with sycamores along its margin" (Day 1853).

As the stream bifurcated in the distributary reach, vegetation would have been minimal, consisting mainly of hydrophytic grasses as the stream was integrated into the larger matrix of oak savanna and grassland before reaching the marsh.

Fish

Fish assemblages in intermittent streams in Livermore-Amador Valley were highly variable depending on local environmental conditions and life history needs. Fish populations used large intermittent creeks such as Arroyo Mocho seasonally, particularly as a migration corridor to other suitable intermittent or perennial habitats with year-round pools found within the upper watershed (Leidy in Stanford et al. 2013:272). The perennial open water of the Pleasanton marsh would have provided important off-channel rearing habitat, especially in dry years. When surface connections between Arroyo Mocho and other intermittent tributaries were made during high flow events, large intermittent tributary creeks functioned as critical migration corridors and potentially significant rearing habitat for steelhead depending on the amount and distribution of annual precipitation.

Case Studies

Arroyo Mocho was controlled by the slope and size of its canyon, which propelled the stream into the open Valley where it built an alluvial fan, braided through it, transitioned to a single-thread channel, and finally bifurcated into multiple distributaries (Figure 3.2). The following case studies delve deeper into the components of the landscape, following Arroyo Mocho downstream.

A summary of historical riparian characteristics along the alluvial reaches of Arroyo Mocho is shown in Table 3.1, highlighting the dominant morphology, substrate, flow characteristics and riparian vegetation patterns during the historical period. These zones correspond generally to two of the three case studies presented in this chapter.

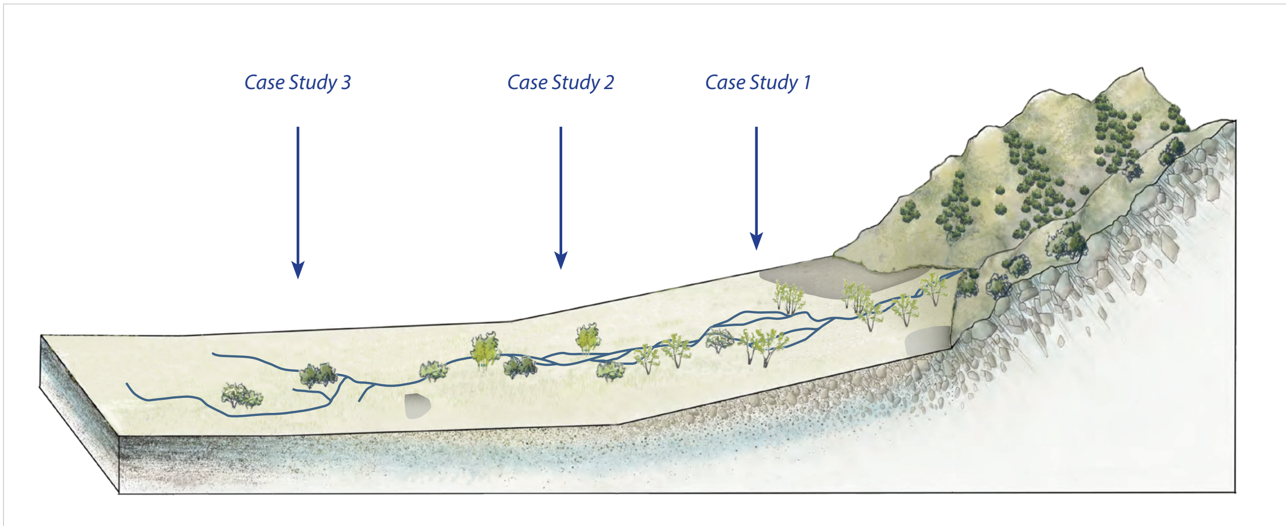


Figure 3.2. Conceptual model of historical Arroyo Mocho, ca. 1800. This diagram shows a simplified oblique view of Arroyo Mocho as it exits its canyon, braids across its fan, and spreads out, losing channel definition and forming distributaries. The graphic shows a gradual fining of bed material, change in relative depth to groundwater (shown in light blue), and corresponding changes in vegetation patterns as the stream flows downslope.

Table 3.1. Riparian characteristics of alluvial reaches of Arroyo Mocho, ca. 1800

Creek	Reach	Case Study	Watershed Area (sq. miles)[1]	Dominant Morphology[2]	Dominant Geomorphic Process [2]	Substrate[3]	Dry Season Flow	Riparian Corridor Width Classes[4]	Riparian Vegetation[5]
Arroyo Mocho	Upper Mocho (canyon mouth to Tesla Road)	--	45	Single-stem, meandering	Production, transport, depositional	Boulders, gravels, sand	Perennial/ Intermittent with pools	200-660 ft (60-200 m)	Sycamore alluvial woodland
	Middle Mocho (Tesla Road to Oak Knoll)	Case Studies 1 & 2	55	Braided	Transport, depositional	Boulders, gravels, sand	Intermittent	660-1320 ft (200-400 m)	Sycamore alluvial woodland
	Lower Mocho (Oak Knoll to distributaries)	Case Study 3	59	Distributary channels	Depositional	Gravels, silt, clay	Intermittent	200-660 ft (60-200 m)	Sycamore, Sparse oak

[1]Watershed area was calculated at the downstream endpoint of each reach using contemporary USGS Streamstats, but is likely representative of the historical drainage area.

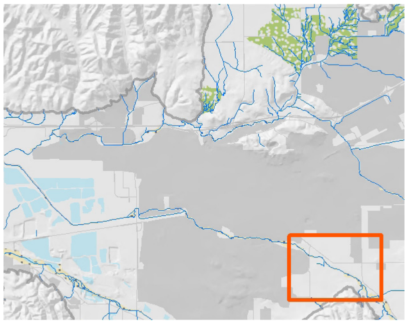
[2]Dominant morphology and process were determined from the mapped form of the creek, our understanding of fluvial geomorphic processes, and geology data.

[3]Substrate classes were developed from historical descriptions, soils and geology mapping, and historical photographs.

[4]Riparian corridor width measures from the outer edge of stream-associated vegetation on one side of the stream to the other, including the stream bed. These widths were based largely on the width of a representative reach in the historical aerial imagery and current geomorphic features in the 2007 LiDAR data (USDA 1940, Sanborn Mapping 2007).

[5]Broad historical riparian vegetation classes were developed from available species data, and describe the inner corridor of riparian vegetation. Further from the creek, riparian vegetation would have included valley oaks and/or sycamores.

CASE STUDY 1: ARROYO MOCHO SOUTHEAST: *ROOM FOR RE-BRAIDED CHANNELS*



PROBLEM STATEMENT

This first case study encompasses the most upstream reach of Arroyo Mocho within the Valley, from just downstream of where the stream diverges from Mines Road on the southeast to Robertson Park on the northwest (Figure 3.3). Management challenges in this reach stem from changes in channel planform and loss of riparian habitat. Arroyo Mocho has been converted from a braided to single-threaded channel along a large segment of this reach to make room for high value agriculture (Figure 3.3). This change in planform, and reduced room for the stream to migrate and braid, has likely reduced naturally-organized in-channel sediment storage throughout the reach and increased sediment transport to downstream reaches, contributing to documented sedimentation problems at Holmes Street Bridge and other locations (see Figure 1.4). The narrowing of the stream corridor has been accompanied by a substantial reduction in the extent of the riparian corridor, including a loss of sycamore alluvial woodland habitat.

UNDERLYING PHYSICAL AND ECOLOGICAL PROCESSES

Historically, this reach of Arroyo Mocho represented a transition zone between the confined, single-threaded channel of the bedrock canyon upstream, and the low-gradient, multi-threaded channel in the Valley downstream. In the canyon, transport of water and sediment (as opposed to storage) were the dominant processes. As the stream emerged from the confined canyon and entered the valley floor, however, the high sediment supply combined with the change in bed slope and the widening of the stream corridor across its alluvial fan supported the formation of a multi-threaded channel and braided bars (in-channel storage) in many places (see Figure 3.2). As the stream flowed over its fan and its slope decreased, it became a losing reach, with surface water gradually sinking into the gravelly substrate and recharging groundwater aquifers. Flooding was frequent, and during heavy floods the stream would overflow its banks, inundating the surrounding floodplain.

Suitable groundwater depths, the presence of alluvial substrates, and variable stream discharges supported sycamore alluvial woodland, a rare California ecosystem type, along much of this reach of Arroyo Mocho (Keeler-Wolf et al. 1996:14-18). Sycamore alluvial woodland is a sycamore-dominated (more than 50% of relative cover in tree layer of *Platanus racemosa)* riparian woodland type that grows along the alluvial benches of braided streams (Keeler-Wolf et al. 1996). The understory includes California buckeye (*Aesculus californica*), blue elderberry (*Sambucus* spp.), and mule fat (*Baccharis salicifolia*), but the habitat type may also include areas of unvegetated channel (Holland 1986). Seasonally dry sycamore alluvial woodland supported a distinct suite of wildlife including yellow-legged frog *(Rana boylii),* horned lizard *(Phrynosoma coronatum frontale),* and lesser nighthawk *(Chordeiles acutipennis)*.

Sycamores likely occurred on in-channel bars as well as banks and terraces within the active floodplain, which are discernible in LiDAR images (Figure 3.1). The sycamores themselves reinforced the braided channel form by stabilizing banks and in-channel bars. The width of the riparian corridor ranged from approximately 200 to 1300 ft (60 to 400 meters) (Table 3.1).

HISTORY OF CHANGES OVER TIME

Though extensive agricultural development had already occurred in this area by 1940, Arroyo Mocho still persisted as a broad, multi-threaded stream along this reach. During the late 20th century, however, farming expanded into much of the historical stream corridor. In the intervening years, large portions of the riparian corridor were cleared, and the stream was converted from braided to single-threaded (Figure 3.3). The stream is now confined to a narrow channel bordered by agricultural land (Figure 3.3c, Figure 3.4). Despite the changes associated with agricultural expansion, the areas surrounding this reach are still relatively undeveloped: farms and vineyards are the predominant land use.

The conversion from a braided to single-threaded channel likely had a significant impact on the sediment transport dynamics of this reach, decreasing sediment deposition and increasing sediment transport by concentrating flows through a single channel, and presumably increasing stage and flow velocities. This

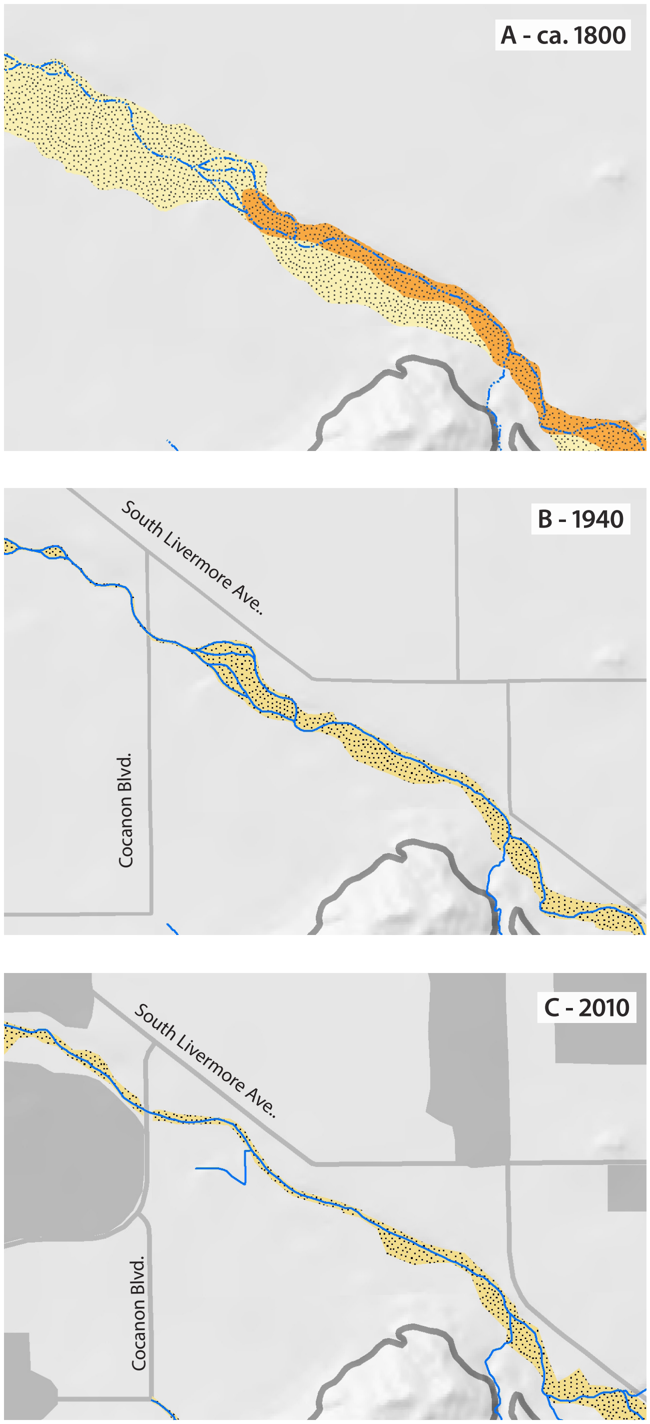


Figure 3.3. Change over time of riparian habitat extent, stream configuration, and extent of impervious surfaces between 1800, 1940, and 2010 on southeast Arroyo Mocho. A. Historical conditions representing ca. 1800 (Stanford et al. 2013). B. Conditions in 1940 (USDA 1940, USGS 1940, 1942). C. Conditions ca. 2010 (USDA 2009, ICF International 2010, SFEI 2011).

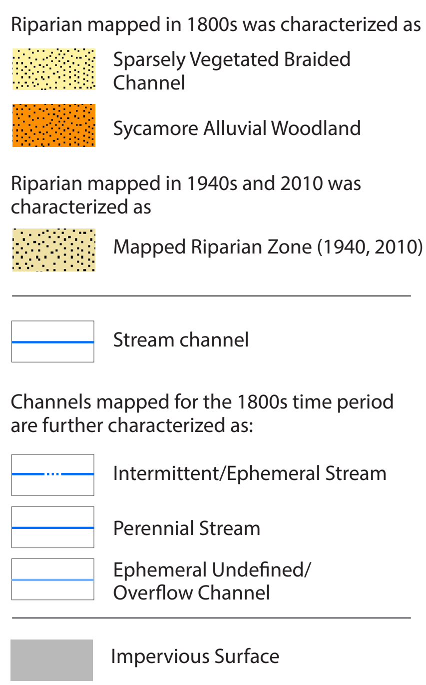
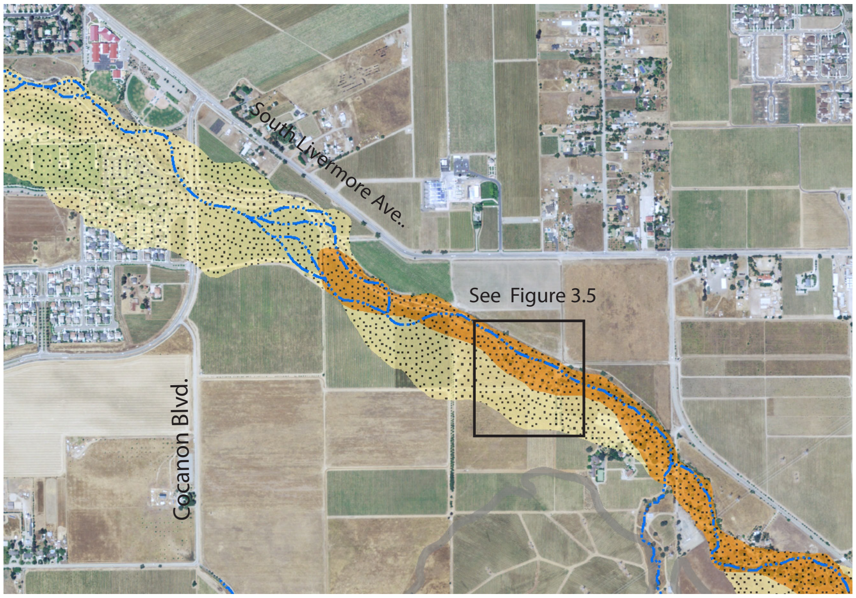


Figure. 3.4. Transformation of upper Arroyo Mocho from a broad, braided channel with sycamore alluvial woodland in the historical period (top, showing historical habitat types over modern aerial) to a narrow single stem channel. This reach holds potential for re-introduction of a braided system in the long term future (bottom), if the land ownership pattern changes. (USDA 2009, Stanford et al. 2013)

Sparsely Vegetated Braided Channel

Sycamore Alluvial Woodland

Intermittent/Ephemeral Stream



change in planform has also likely impacted the hydrology of the stream and thus the channel geometry. With confined flows through this reach, and elevated stage and water surface slope, shear stress on the banks and bed may have increased, causing bed lowering and decreasing the time to peak discharge further downstream.

The South Bay Aqueduct (SBA), constructed in the early 1960s as part of the State Water Project (SWP), discharges water into Arroyo Mocho just upstream of the boundary of Case Study 1 (DWR 2001). Water inputs from the SBA, as well as runoff from surrounding urban areas, may have increased base flows and reduced stream flow variability. The altered hydrology has likely increased the density of species such as willows and reduced the extent of xeric-adapted habitats, such as sycamore alluvial woodland.

FUTURE POTENTIAL

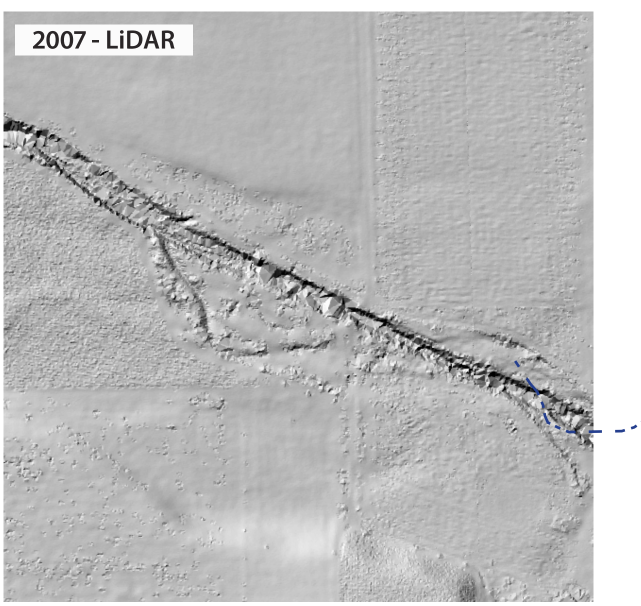
Although a large portion of this reach of Arroyo Mocho has been artificially confined to a single-thread channel, the underlying physical controls that historically maintained a braided channel – and associated watershed functions such as sediment storage and groundwater recharge – remain relatively unchanged. Arroyo Mocho's large, undammed watershed still produces a large supply of coarse sediment, while other fundamental physical drivers – the reduction in stream gradient and change in confinement occurring at the mouth of the canyon – still promote sediment deposition, though it is happening in different places than it did historically. The fact that these physical controls are relatively intact suggests a high potential for the reestablishment of natural sediment dynamics and a broad braided channel along portions of this reach. Allowing the channel to widen and braid could potentially help to restore riparian habitats and increase in-channel sorted sediment storage upstream. The increase in sediment storage on in-channel bars that would accompany such a management action might help to restore the balance of sediment in the upper Arroyo Mocho reach, thus potentially limiting sedimentation problems at downstream bridge footings. Restoration of a braided channel would also increase the travel time and decrease peak flows by broadening the hydrograph. Sediment transport modeling should be used to assess the volume, storage potential, and impact on flood capacity of such a restoration action.

Several locations within this reach appear to have high potential for re-introduction and self-maintenance of a multi-threaded channel. Near the center of the case study, a small unfarmed area that currently supports riparian tree cover may have supported a multi-threaded reach at varying times in the recent past, as can be seen in LiDAR images (Figure 3.5). Approximately ¼ mile further downstream is another, larger area that was mapped as braided in the early 19th century (see Figure 3.4). Although the modern single-threaded channel is closely surrounded by farmland (especially at the second location), these areas represent potentially promising sites for restoration of braided reaches in the future. Less important than the specific site for re-engaging channels is the concept of strategically establishing a wide channel corridor through this reach, which would potentially provide multiple benefits for downstream management, including in-channel storage of coarse sediment, decrease of slope, possible flood attenuation, and wildlife benefits.

Several constraints should be recognized with this type of management strategy. First, land ownership and land uses are the primary concerns and should be considered with care as Zone 7 is not a land use authority. Second, the degree to which the channel is incised will impact the potential to recreate a braided reach, and may necessitate an untenable volume of soil excavation. Third, the hydrology in this reach (and all of lower Mocho) has been altered by inputs from the South Bay Aqueduct. Given the managed perennial (and sometimes intermittent) flows release from the aqueduct, it may not be possible to recreate the intermittent and flashy flows which historically supported sycamore alluvial woodland in this reach (Gillies 1998), although there is evidence for persistence and regeneration of sycamore alluvial woodland in other nearby reaches.

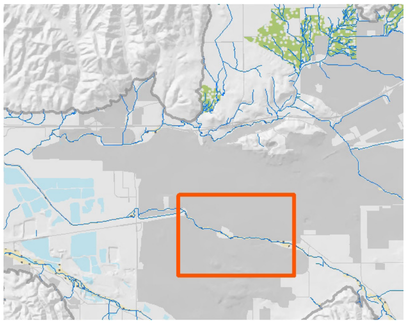
This case study explores management approaches that are necessarily part of a longer term strategy for watershed management. The land in question here is in private ownership and is used for high value agriculture, and thus may only become available after decades have passed. Nonetheless, Zone 7 might be able to plan for this type of land purchase in the longer term future, building it into a multi-step watershed plan for sediment management and riparian forest regeneration.

Figure. 3.5. Future potential for restoration of braided reach on Arroyo Mocho. This reach of the creek shows the topographic signatures of a multi-thread channel, and is not currently in cultivation (see inset box on Figure 3.4). There appears to be a high potential for increase in-channel storage and channel widening in this reach. (Sanborn Mapping 2007, USDA 2009)



CASE STUDY 2: ARROYO MOCHO (HOLMES STREET BRIDGE TO MADEIROS PARKWAY)

BRAIDING STRATEGIES FOR SEDIMENT STORAGE



PROBLEM STATEMENT

The second case study is located just downstream of Case Study 1, and includes the portion of Arroyo Mocho between Robertson Park and Stanley Boulevard, which together create a uniquely continuous wide riparian corridor within the urban fabric of Livermore (Figure 3.6). This segment of Arroyo Mocho supports a relatively mature riparian forest with an abundance of native tree species. It is neither channelized nor significantly incised, though it has a dominant low flow channel (it is not actively braided). The stream is separated from the urban development of Livermore by a narrow corridor of undeveloped public land. The primary management problem in this area is the significant sedimentation occurring upstream of Holmes Street Bridge and Stanley Boulevard Bridge (located at the downstream end of the case study), necessitating periodic excavation (Figure 3.6) . In addition, the stream segment between Stanley Boulevard and Holmes Street Bridge is cited as one of the "primary areas subject to flooding" (Zone 7 2006:3-6) because of lack of capacity due to in-channel sediment deposition.

UNDERLYING PHYSICAL AND ECOLOGICAL PROCESSES

As it progressed across its alluvial fan, Arroyo Mocho continued to deposit sediment and lose stream power. Surface flow declined as water percolated through the coarse gravels, recharging underground aquifers. Historical sources indicate that Arroyo Mocho maintained a wide, braided channel through much of this reach as well (Figure 3.6a). By the approximate location of the modern-day Holmes Street Bridge, however, Arroyo Mocho's stream power and ability to transport sediment naturally declined to the point that the stream was unable to maintain its braided form and it transitioned to a single-threaded channel, depositing more sediment in the process.

Corresponding to the decrease in surface water availability as Arroyo Mocho flowed across the Valley through this reach, sycamore alluvial woodland graded into an even more sparsely-vegetated riparian corridor with occasional oaks (*Quercus* spp.), sycamores (*Platanus racemosa*), willows (*Salix* spp.*),* and shrubs (i.e., mulefat *(Baccharis salicifolia))* (Figure 3.6a). In the northwestern portion of the case study, near present-day Stanley Boulevard, a fringe of seasonal wet meadow bordered the stream to the north. Vegetation likely included grasses and a significant component of obligate and facultative wetland species such as wire rush (*Juncus balticus),* irisleaf rush *(Juncus xiphiodes),* buttercup *(Ranunculus californicus),* and blue eyed grass *(Sisyrinchium bellum)* (Holstein 2001).

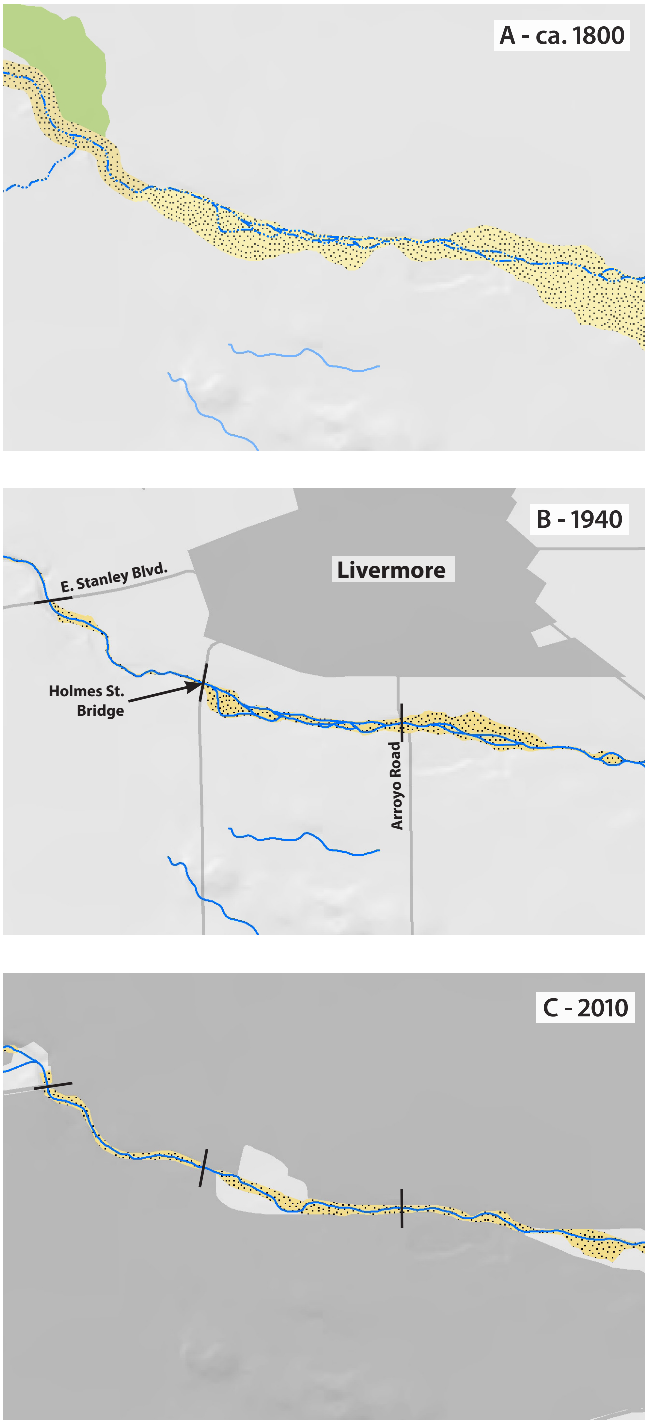
HISTORY OF CHANGES OVER TIME

This reach of Arroyo Mocho runs through the heart of Livermore, and has thus been heavily impacted by urban development. By the mid-1900s, agriculture dominated the area south of Arroyo Mocho and had begun to encroach into the riparian corridor, but much of this reach still supported a broad and sparsely vegetated riparian zone. By 1980, the farms had been replaced with residential development, and large portions of the riparian corridor had been paved over. Today, with a few exceptions such as Robertson Park and Madeiros Parkway where a wider corridor of open space remains, the stream flows through a confined corridor closely bounded by residential development (Figure 3.6).

Holmes Street Bridge was constructed at the point where Arroyo Mocho historically shifted from a braided to a single-threaded channel. This was likely not a coincidence, given that the thinnest part of the channel would have been the most convenient place to build a bridge. However, the bridge likely further constricted the channel in this area, causing a bottleneck for water and sediment transport and resulting in the buildup of sediment behind the bridge (Figure 3.7).

The structure and composition of riparian vegetation in this reach have changed relative to historical conditions, though elements of the historical corridor still remain. Vegetation density has increased substantially, likely because of increased dry season flows resulting from urban runoff and inputs from the SBA. Through field observations (see Appendix B), we calculated average tree density between Concannon Blvd and Holmes Street to be approximately 65.7 trees/acre (this stretch of the river spans most of Case Study 2 and extends approximately 0.6 miles east into Case Study 1) (Figure 3.8). Average tree density was relatively high in the channel and on the inner bench (175.5 and 157.9 trees/acre, respectively), but much lower in the outer bench/floodplain (21.3 trees/acre). Sycamore alluvial woodland would generally have a lower tree density throughout alluvial distributions in central California (Gillies 1998, Keeler-Wolf et al. 1996).

The channel corridor currently supports a diversity of height, structure, and species, though species composition has changed dramatically. While the historical corridor



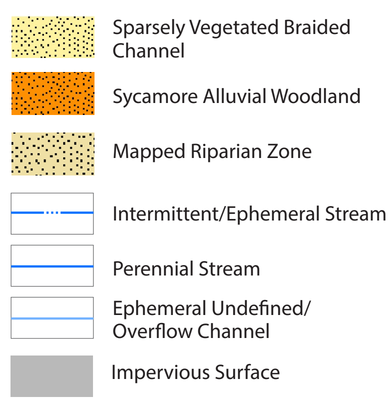


Figure 3.6. Change over time of riparian habitat extent, stream configuration, and extent of impervious surfaces between 1800, 1940, and 2010 on Arroyo Mocho (Robertson Park and Madeiros Parkway). A. Historical conditions representing ca. 1800 (Stanford et al. 2013). B. Conditions in 1940 (USDA 1940, USGS 1940). C. Conditions in 2010 (USDA 2009, ICF International 2010, SFEI 2011).

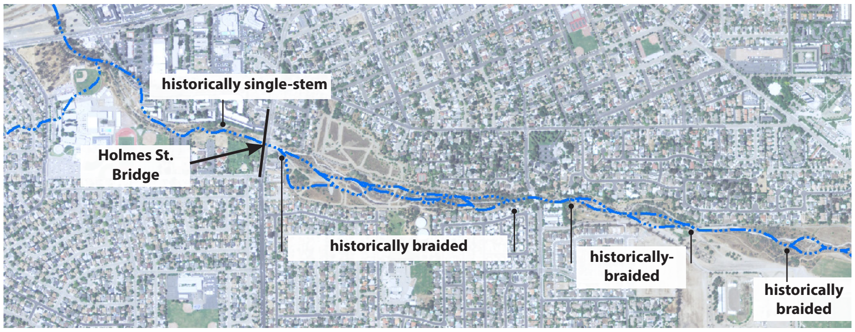


Figure. 3.7. Historical transition from braided to single stem channel at Holmes Street Bridge. This image overlays the historical channel network (Stanford et al. 2013) on the modern aerial imagery, highlighting the natural shifts in channel planform.

was a mix of sycamores, oaks, willows, and shrubs, today willows dominate the low flow channel, accounting for 81% of recorded trees. Seedlings or saplings account for 99% of these willows (see Appendix B). The benches contain a more even mix of (mostly native) tree species, including black walnut, California buckeye, Fremont cottonwood, valley oak, sycamore, eucalyptus, and ornamentals. Mature sycamores have persisted in a number of locations on the inner and outer benches of this reach, most notably in the southwestern portion of Robertson Park near the Del Valle Mobile Home Park and in the southwestern portion of Madeiros Parkway near Holmes Street (Figure 3.9). Mature sycamores were also observed in the backyards of private homes and in the parking lot of Roberston Park, often up to 100 m from the active channel; these trees most likely established during past floods when these areas were part of the active floodplain. Though these sycamores are no longer connected to the hydrologic regime of the channel, we might assume that they are being supported by adequate levels of groundwater. We also observed some sycamore regeneration, concentrated in the inner benches within Madeiros Parkway and several other locations, though regeneration rates appear to be fairly low (Appendix B, Figure B8).

FUTURE POTENTIAL

Although sedimentation at Holmes Street Bridge is a costly management problem, it is informative to recognize that this reach of Arroyo Mocho was in fact a depositional zone historically. Thus, rather than being an aberration due to human interference, the sedimentation at Holmes Street Bridge likely represents the continuation (and perhaps amplification) of a natural process. Nevertheless, the conversion of the channel from braided to single-threaded in this reach has likely

Figure. 3.8. Tree density by geomorphic zone on Arroyo Mocho. We mapped tree density by species type and age class along Arroyo Mocho, focusing on Robertson Park and Madeiros Parkway. Early results showed that while there is a wide corridor of potential riparian habitat, the density of trees is highest in the channels in Robertson Park, with a slightly more even distribution of densities in Madeiros Parkway. For more detail see Appendix B. (USDA 2009)

Trees per acre

- 4.5 - 51.2
- 51.3 - 98.5
- 98.6 - 152.7
- 152.8 - 260.2
- 260.3 - 485.8

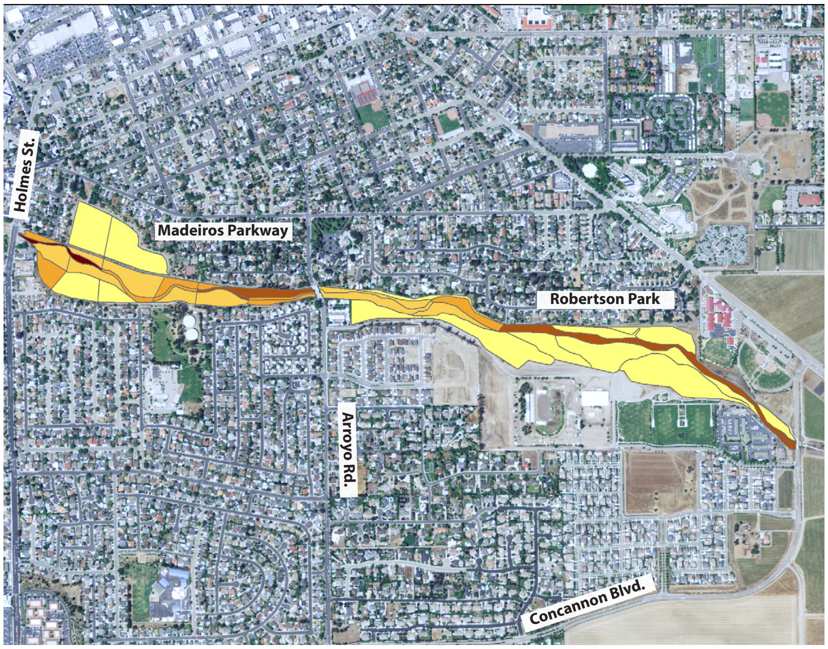


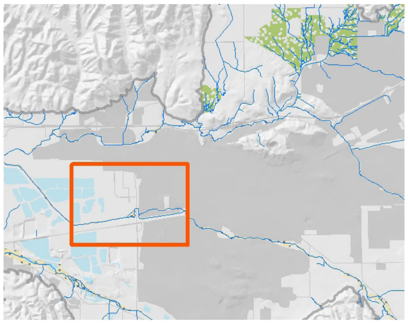
Figure. 3.9. Sycamores observed on mounds in parking lot of Robertson Park. Sycamores (*Platanus racemosa)* were observed growing up to 100 m away from the current low flow channel, but within the bounds of the historical extent of mapped riparian habitat (Stanford et al. 2013). Dendrochronology might be used as a tool to reconstruct disturbance regimes in this reach. (photo by Sean Baumgarten, November 1, 2012)

Figure 3.10. Field-observed inactive side channels. Light blue lines indicate the location of several swales or inactive side channels that were observed at low flow conditions in the field (November 1 and 13, 2012). Further observations should be made as to whether these are activated in high flows, or if they could be reconnected with the main stem without the context of future park design and management. (Sycamores shown in Figure 3.10 are circled in red)

exacerbated the sedimentation problem by increasing stream power and sediment transport capacity along some segments while concentrating sediment deposition in others.

One option to address sedimentation would be to redesign Holmes Street Bridge to reduce the constriction of the channel, thus making the site less susceptible to sedimentation. This approach would likely only provide a partial solution to this management problem, however, and would do little to advance other management goals such as riparian habitat restoration. A complementary solution could involve restoration of some components of the historical floodplain and braided stream morphology. As previously discussed, this reach of Arroyo Mocho is largely confined by intensive urban development, severely constraining options for floodplain restoration. However, there appear to be some opportunities for limited restoration of additional channels and sections of floodplain through the two parks. More specifically, inactive side channels or other locations for braided reach restoration were identified through our field and GIS analyses (Figure 3.10). However, sedimentation may continue to be a management challenge in this reach.

Cumulatively, increasing braiding and thus in-channel storage as explored in Case Studies 1 and 2 would potentially alleviate some of the sediment build up at the Holmes Street and Stanley Boulevard bridges as well as increase channel complexity and in-stream habitat. These first two case studies are presented as separate sites, but shoudl be considered in tandem to create beneficial impacts on the sediment dynamics of the system. One major constraint that could affect the success of this management strategy is the altered hydrology of the stream system relative to historical conditions. Increased base flows now encourage the growth of relatively dense riparian vegetation, which constricts the channel and inhibits lateral movement. Some vegetation control and ongoing maintenance may therefore be required along the low flow channel so that braiding could take place. Though braided channel morphology historically supported sycamore alluvial woodland, this habitat type may or may not be able to re-establish given the changed flow conditions. As evidenced by the sycamore saplings currently re-establishing along the main channel, however, there is a high likelihood that sycamores could persist in this reach as part of a mixed riparian forest.



CASE STUDY 3: ARROYO MOCHO DISTRIBUTARIES
RECONNECTING THE CHANNEL TO THE CHAIN OF LAKES

PROBLEM STATEMENT

The third Arroyo Mocho case study extends from Stanley Boulevard to the point where the stream turns north through the Chain of Lakes (Figure 3.11). The first portion of the reach to the east of Isabel Avenue consists of two separate channels: the flood control channel adjacent to Stanley Boulevard and an "alternate" channel running through a residential neighborhood approximately 0.1 miles to the north. The second portion of the reach to the west of Isabel Avenue consists of a single flood control channel.

Significant sedimentation is occurring within the flood control channel west of Isabel Avenue and in the alternate channel east of Isabel Avenue (see Figure 1.4). One outcome of this sedimentation is a reduction in channel capacity, leading to an increased risk of flooding.

This reach is also characterized by poor quality riparian habitat. East of Isabel Avenue, the riparian corridor is dominated by non-native grasses along a trapezoidal flood control channel with minimal native habitat value. The alternate channel to the north has a diverse mix of native and non-native riparian species and high vegetation density (Figure 3.12). West of Isabel Ave, the flood control channel is dominated by eucalyptus (Figure 3.13).

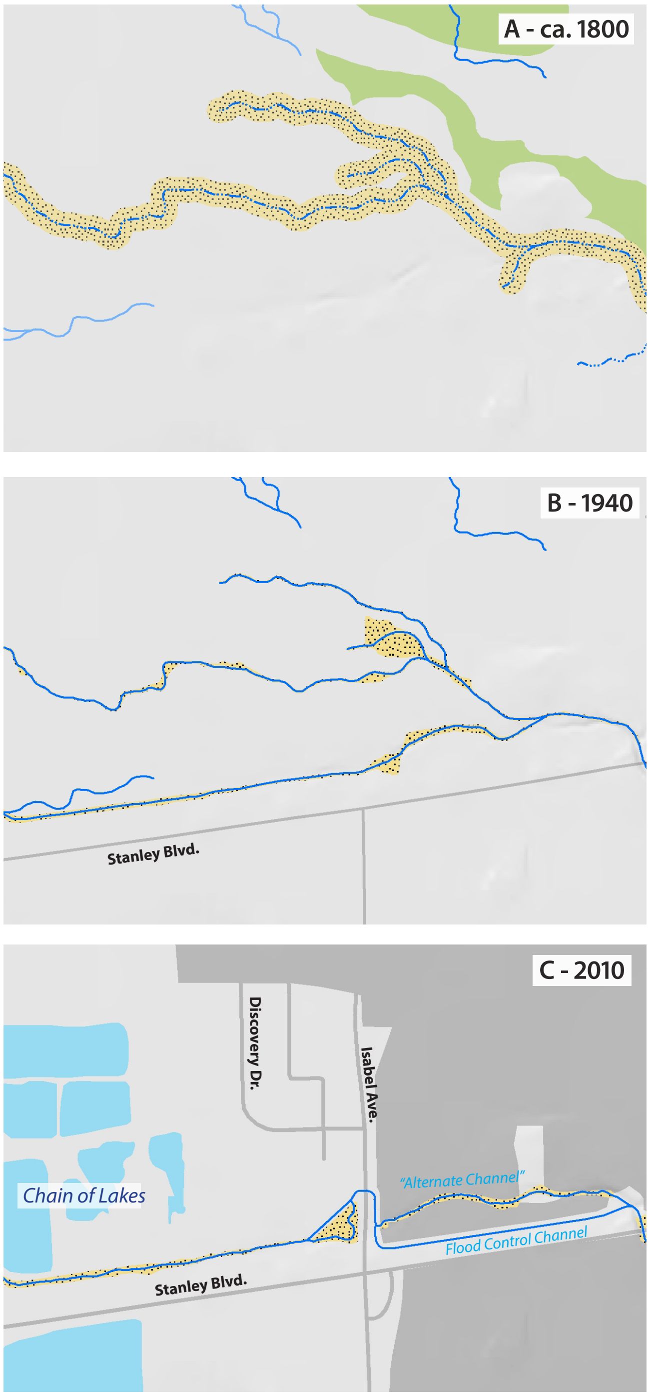


Figure 3.11. Change over time in riparian habitat extent, stream configuration, and extent of impervious surfaces between 1800, 1940, and 2010 on Arroyo Mocho distributaries. A. Historical conditions representing ca. 1800 (Stanford et al. 2013). B. Conditions in 1940 (USDA 1940, USGS 1940). C. Conditions in 2010 (USDA 2009, ICF International 2010, SFEI 2011).

- Sparsely Vegetated Channel
- Intermittent/Ephemeral Stream
- Perennial Stream
- Ephemeral Undefined/ Overflow Channel
- Impervious Surface

UNDERLYING PHYSICAL AND ECOLOGICAL PROCESSES

Historically, this reach was the terminus of Arroyo Mocho's alluvial fan and the site of its distributaries. Except during very high flow conditions, the remaining surface flow spread out and sank into the ground. As a result, this area functioned as an important groundwater recharge reach (Williams 1912), and did not support a riparian corridor of trees - rather, the distributaries flowed through an oak and grassland matrix.

To the west of Oak Knoll Cemetery, Arroyo Mocho crosses the Livermore Fault, which was one of the factors that may have caused the stream to sink subsurface. While the exact position at which Arroyo Mocho spread into distributary channels would have varied over time, historical maps and GLO survey notes converge on this as a general location of this transition (see Stanford et al. 2013). Subsurface flow continued east towards Pleasanton marsh (Williams 1912). Although the substrate in this part of lower Arroyo Mocho was dry and gravelly, the presence of the Livermore Fault created a series of springs (Tibbetts 1907, Unruh and Sawyer 1997). Travelling south along current Isabel Avenue, surveyor Sherman Day (1853) crossed an "open gravelly plain" and described "water in a swamp slough" in July 1853. This "swamp slough" was likely a small perennial wetland. By July, Arroyo Mocho would have completely dried up, so a wet slough must have been fed by a local spring. The presence of the perennial wetland and associated spring may have exacerbated the need for drainage, and preempted the early ditching of Arroyo Mocho to the south.

HISTORY OF CHANGES OVER TIME

Stream morphology and function in this reach have undergone dramatic changes from historical conditions. By 1889, and possibly as early as 1878, a ditch had been constructed to bypass the distributaries and rapidly convey streamflow westward and then northwards towards a confluence with Arroyo Las Positas. However, Arroyo Mocho did not maintain surface flow through the ditch throughout the year. Civil engineer Cyril Williams noted, "In ordinary or critical years the Arroyo Mocho Creek sinks into the Livermore Valley gravels, and seldom in such years reaches the Laguna Creek as surface flow" (Williams 1912:571; see also Gutmann 1919:6). Flows remain intermittent today, though they are augmented by the inputs of South Bay Aqueduct.

Figure 3.12 View of northern alternate channel (taken from Rockrose Street facing east). This small channel is densely wooded with mixed native riparian trees and eucalyptus (Photo by Sean Baumgarten, November 15, 2012).

Figure 3.13. Arroyo Mocho near Hagemann Bridge. Simplified channel lined with dense eucalyptus trees in creek along Stanley Blvd where historically the stream spread into distributaries (Photo by Sean Baumgarten, November 15, 2012).

Figure. 3.14. "Hauling gravel from Mocho Creek bed." Arroyo Mocho transported large volumes of sediment, including cobbles and gravels, which early residents of the Valley excavated for road surfaces long before commercial mining began in the area. (Photo #N252, courtesy Livermore Heritage Guild)

After the initial ditching, the basic channel planform apparently remained unchanged until 2000, when a flood control channel was constructed east of Isabel Ave (Zone 7 2006:3-31). Several years later, the Isabel Ave underpass was created.

Early residents of Livermore Valley began excavating gravel from the Arroyo Mocho creek bed for road surfaces (Figure 3.14). An 1894 newspaper editorial, for example, complained, "When will the powers that be give us needed bridges – instead of everlastingly hauling gravel?" (Echo 1894b). Commercial gravel mining was initiated in the early-mid 1900s and continues today within parts of the "Chain of Lakes", which line the channel from approximately ½ mile downstream of the Isabel Avenue crossing to the confluence with Arroyo Las Positas (Figure 3.15). Table 3.2 shows the acreage of gravel quarries in the Valley increasing over time.

As much as the planform of Arroyo Mocho has deviated from its historical position in this reach, there is some surprising evidence of geomorphic processes and subsurface hydrology operating even into the early 21st century. Google Earth Imagery from 1993 -2005 reveals that Arroyo Mocho's distributaries may still have been expressed at that time, varying in configuration from year to year, indicating that subsurface flow spreading from the fan of Arroyo Mocho may have continued to escape confinement and spread across the floodplain, even under the nearby housing development. It is possible that while the surface flow of Arroyo Mocho was moved several hundred feet to the south, the confinement of subsurface flow was less effective. In 2007, roads and a skeleton of development were created, and in subsequent aerial photographs, the distributaries are no longer observed as surface features (Figure 3.16).

The riparian vegetation cover in this reach has undergone dramatic changes over the past century. Historically, the distributaries discharged into grassland dotted with occasional oaks. Aerial photographs from 1940 show a sparsely vegetated channel closely bounded by farmland (Figure 3.16a). Today, the flood control channel east of Isabel Avenue is dominated by non-native grasses and has little habitat value. The alternate channel to the north supports a dense riparian forest of native and non-native species, which we calculated has an average tree density of 358.1 trees/acre. West of Isabel Avenue, the channel is lined by rows of mature eucalyptus, which account for more than 80% of the recorded trees along this portion of the riparian corridor (though we did observe occasional native riparian trees). Figure 3.17 shows the densities of

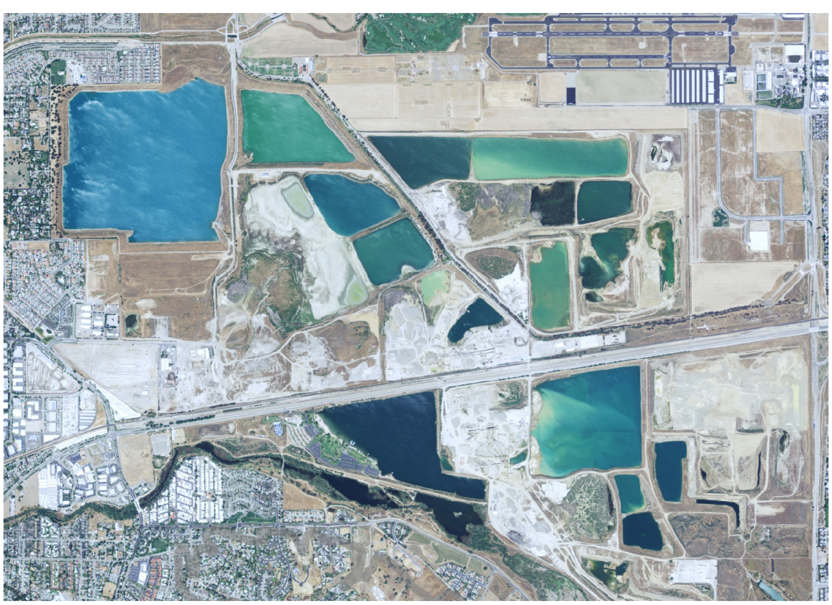


Table 3.2. Acreage of gravel quaries over time

Year	Acreage
1800	0
1940	Not mapped
1980	590*
2012	903*

* From Zone 7 estimates

Figure. 3.15. Contemporary aerial of the Chain of Lakes (USDA 2009).

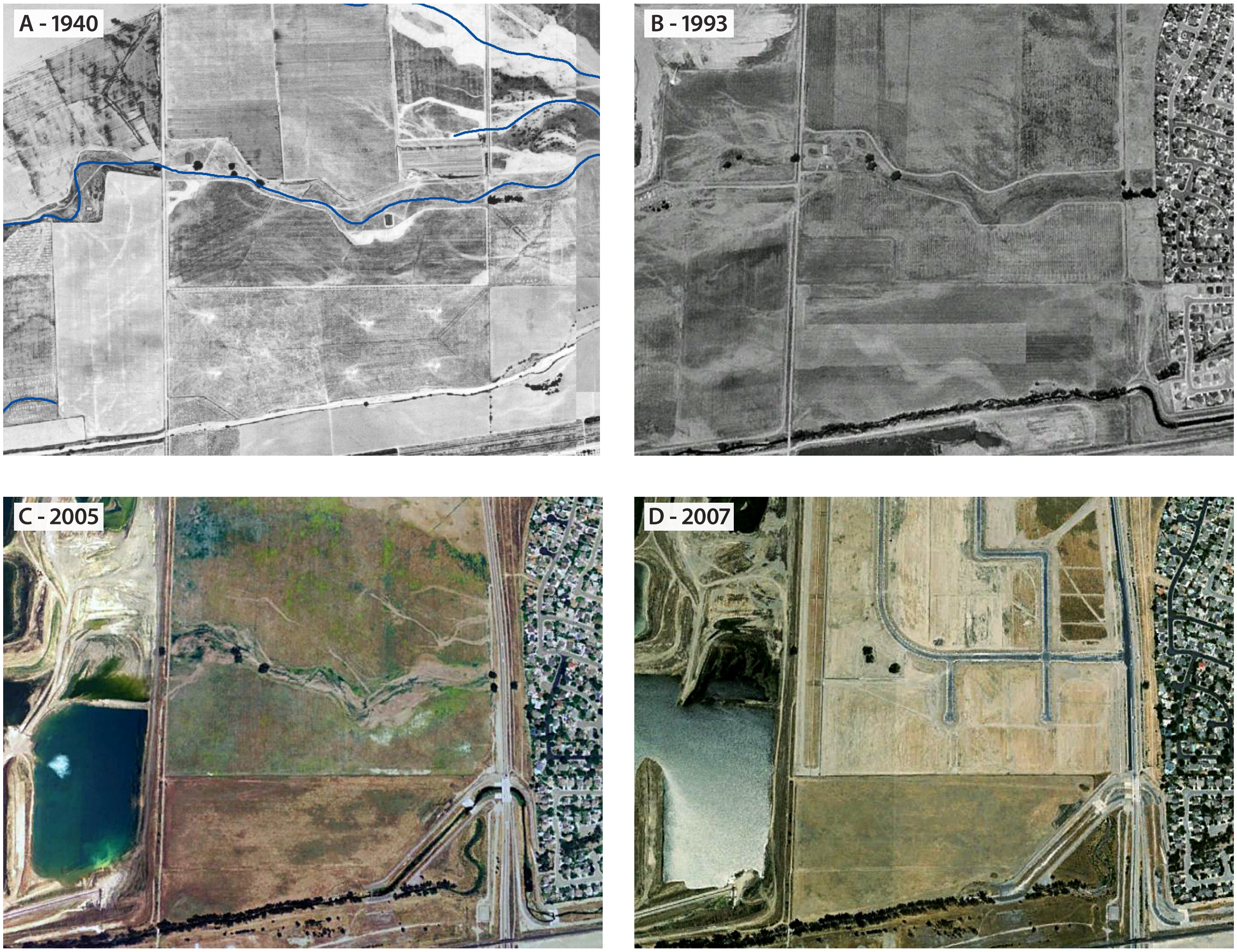


Figure 3.16. Arroyo Mocho distributaries. Aerial photos from1940, 1993, 2005, and 2007 show the persistence of Arroyo Mocho's distributaries decades after ditching and urbanization pressures. Until the new Discovery Drive was build in the late 2000s, evidence of surface flow into the Chain of Lakes matches with the historical location of the distributaries of Arroyo Mocho (USDA 1940, Google Earth 1993, 2005, 2007). Historical streams are overlaid on the 1940s aerial (A).

trees in this case study. The high densities are especially striking in comparison to the particularly low densities of oak that dotted this landscape in the historical period.

FUTURE POTENTIAL

Because the site through which Arroyo Mocho's distributaries historically flowed is still relatively undeveloped, and because Zone 7 is set to acquire several parcels of nearby land when the gravel mining operation halts in 2030, a unique opportunity for floodplain restoration exists that could help to address some of the persistent management problems in this reach. In the short term, Zone 7 might consider reconnecting one or several distributaries through the field just north of the flood control channel, west of Isabel Avenue. Allowing Arroyo Mocho to re-occupy the recently-used flow paths would allow the agricultural field to function as a recharge area during high flows, helping to decrease flood stage and providing important off-channel habitat.

Over the long term, establishing a seasonal connection between Arroyo Mocho and the gravel pits could provide multiple benefits for watershed management and habitat enhancement. The diking of the Pleasanton marsh resulted in the elimination of off-channel habitat in the Livermore-Amador Valley. Loss of this habitat is likely to limit the recovery potential for federally-listed salmonids. Further, the effects of floodplain pit excavation often include channel capture, bedload trapping and channel incision, and altered water tables. Research on the middle Russian River suggests that former gravel pits could to be modified to re-create ecologically productive off-channel habitats, including shallow emergent marsh and floodplain habitats (Cluer et al. 2009). "Reclaiming" some of the Chain of Lakes could potentially offer an opportunity for the re-creation of significant acreages of off-channel habitat, if extensively reshaped and seasonally connected to the main stem of Arroyo Mocho. Researchers note that salmonid predation risks are outweighed by the population-level benefits from growth provided by rearing habitat if sufficient cover and appropriate conditions are created (Cluer et al. 2009). However, hydraulic connections between the main channel and the ponds need to be carefully designed, with special attention paid to physical, biological, and chemical issues such as topography/elevation, water temperature and water quality, and timing of life history migration patterns of fish populations. Hydraulic modeling and sediment transport analysis is needed to estimate the effects of sedimentation expected from a seasonal connection to the Arroyo Mocho mainstem, or the distributaries, and over what time scale the ponds and the channel would evolve.

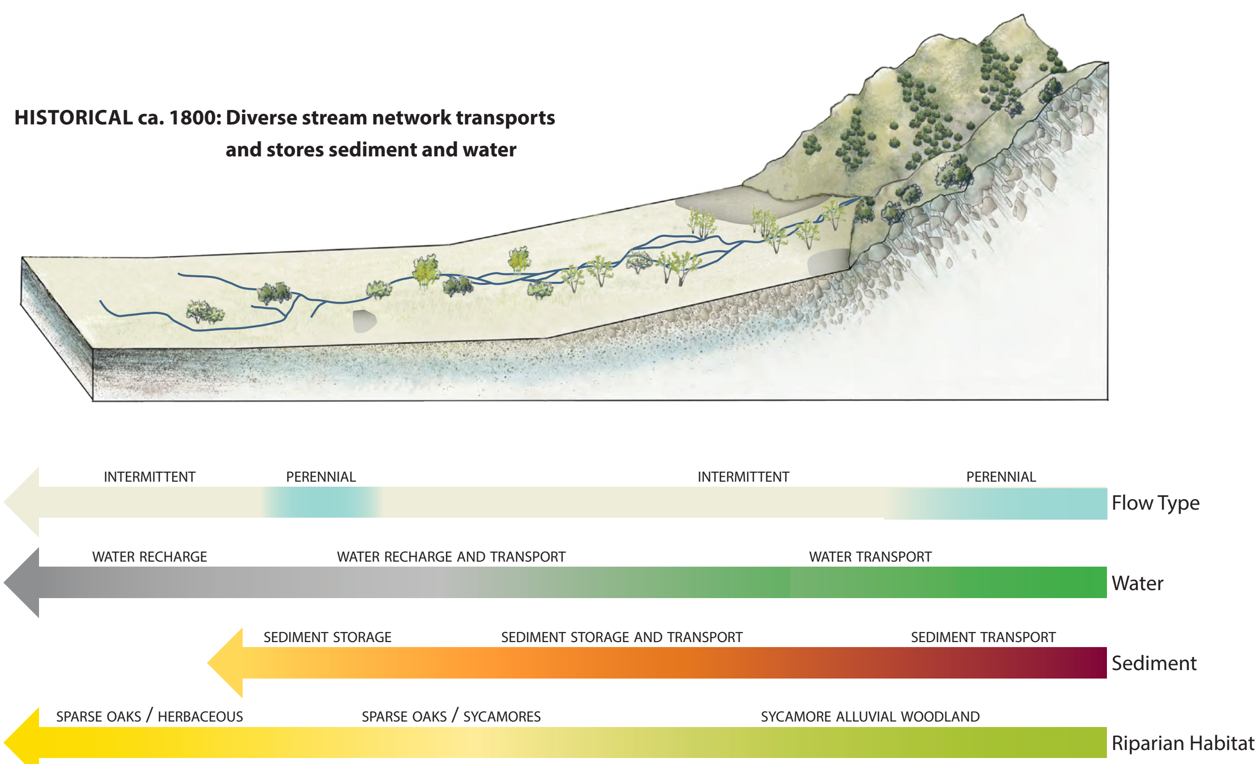
If pursued, the gravel pits would accommodate high flows and act as a potential sediment sink, as has occured on the Passalaqua Pit of the Russian River (Cluer et al. 2009). The pits could be re-engineered to provide a substantial amount of wetland habitat, by constructing gently-sloping banks to maximize the area of shallow water for fish at a range of water levels. Gently sloping banks also favor riparian vegetation establishment because there are larger areas with shallow water table. The Chain of Lakes may have the potential to support many of the functions historically provided by the Pleasanton marsh complex. As shown by the persistence of Arroyo Mocho's distributaries, many historical processes are still acting on this landscape, and these processes can be harnessed through a range of design and management approaches to address flooding, sedimentation, habitat loss, and other challenges (Figure 3.18).

Figure 3.17. Mapped tree density in Case Study 3. We mapped tree density by species type and age class along the Stanley reach of Arroyo Mocho. The side channel (north of the flood control channel) was particularly dense with a mix of native and non-native riparian trees. The downstream reach was still fairly dense by historical standards, but was composed of mostly non-native stands of eucalyptus. See Appendix B for more detail.

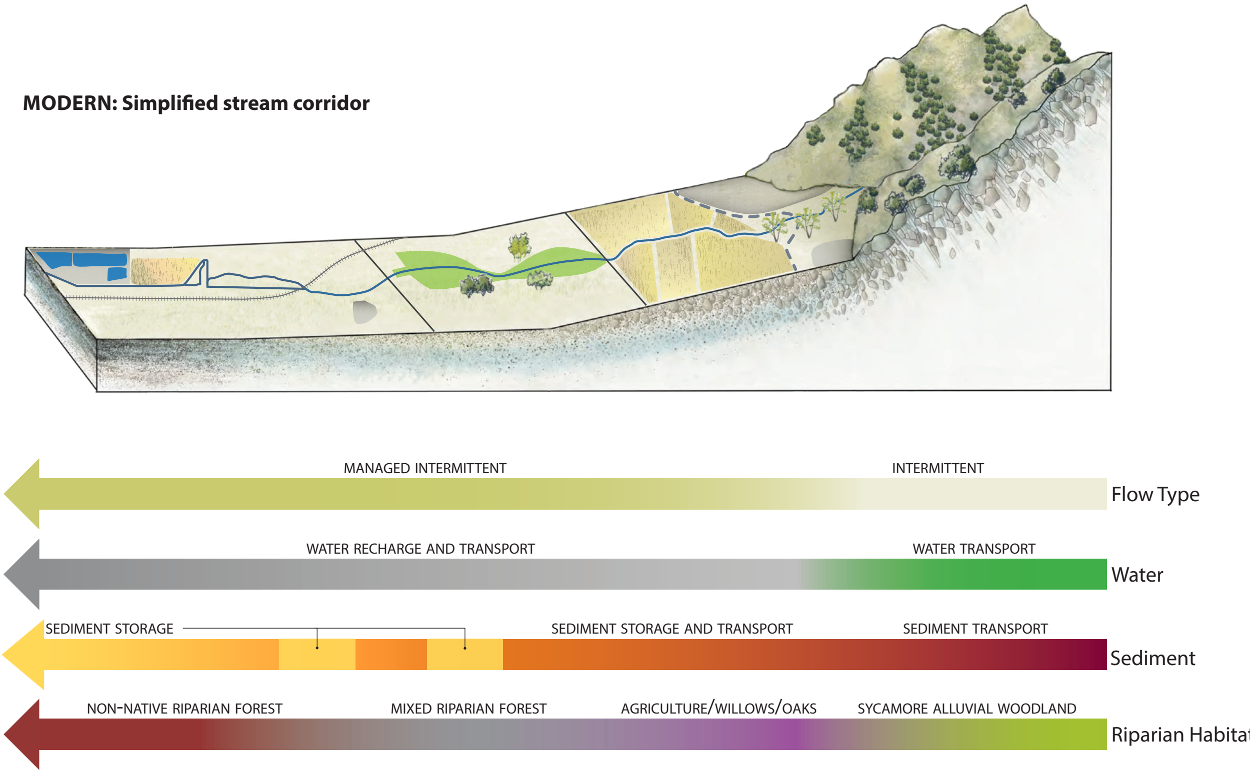
Conceptual Models of Arroyo Mocho Evolution

In this section, we present past, present and future conceptual models of Arroyo Mocho. These three oblique views represent conceptually the configuration of the stream: its substrate, slope, form, vegetation, and general surrouding land use. This is shown conceptually over three time periods: the historical period, present day conditions, and projecting into the future based on the case studies presented above (Figure 3.18). Below each graphic, we illustrate general gradients of different important physical and ecological controls on the system. These include seasonality of water flow, water recharge/transport, sediment dynamics, riparian character. While many of the underlying physical parameters have stayed the same, these surface expressions of water, sediment and vegetation have vastly changed, and thus provide a window into the potential for reestablishment of certain historical functions in certain places--or the use of these functions in different places, more appropriate for the modern landscape. For example, in a future scenario for Arroyo Mocho (opposite page), the distributaries are reconnected to the ditched channel and allowed to flow into the gravel ponds (in the long term). The vegetation, surface water, and sediment patterns designed for this reach may be more succesful when managed in concert with the patterns and processes illustrated in these conceptual models. Finally, the results of these case studies are meant to be taken as a group, or as a vision for this reach of Arroyo Mocho. Individually, these actions may incrementally increase habitat function and decrease management problems, but the goal of these conceptual models is to envision the stream as a unit, and plan cumulative restoration projects and management actions that together add up to a healthier, better functioning watershed.

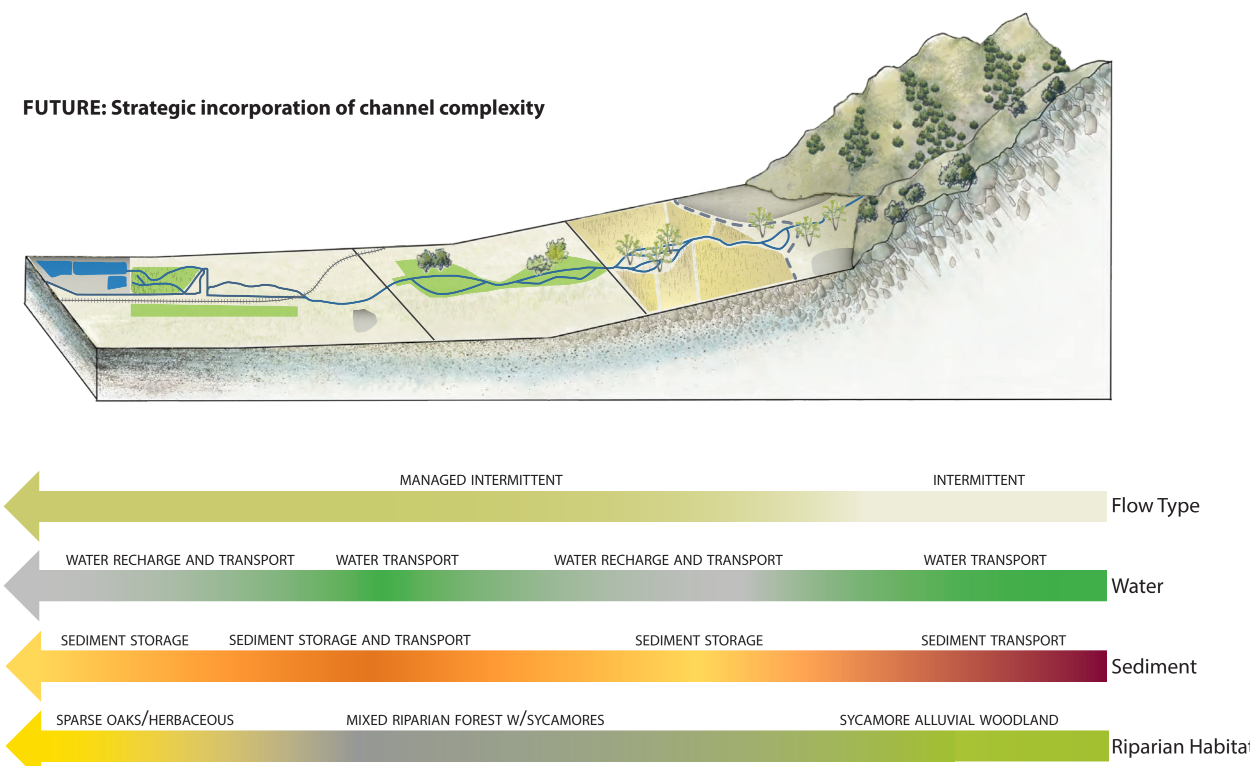
Figure. 3.18. Past, present, and future conceptual models of Arroyo Mocho from the canyon to the Chain of Lakes.



MODERN: Simplified stream corridor



FUTURE: Strategic incorporation of channel complexity



Arroyo Las Positas historical ecology background

Though they shared some attributes, such as intermittent surface flow, Arroyo Mocho and Arroyo Las Positas were historically very different systems that provided distinct ecological functions and supported a wide range of habitats. Many of the processes and drivers that defined these systems historically, especially differences in climate and geology, are still active and continue to influence the systems in different ways. Thus, while the valley floor portions of Arroyo Mocho and Arroyo Las Positas currently face some of the same management challenges, it is important to recognize that the underlying causes of these challenges are different for the two systems. The most effective strategies to address these challenges will most likely involve place-based solutions that factor in the historical and landscape contexts.

Morphology and historical sediment supply

Arroyo Las Positas currently drains 31 square miles (81 km^2) of eastern Livermore Valley, and flows west across the northern end of the down-dropped valley. It is intersected perpendicularly numerous times by a number of small creeks draining the northern hills. Together, Arroyo Las Positas and its tributaries fed the seasonal wetlands in the area by spreading across the Valley in discontinuous, often undefined channels (Higley 1857, Whitney 1873, Allardt 1874, Nusbaumer 1889, Westover and Van Duyne 1910).

Compared with Arroyo Mocho, which carried a high supply of coarse sediment, Arroyo Las Positas most likely transported a relatively low load of fine sediment per unit area. Three main factors were responsible for this difference: 1) Arroyo Las Positas drained a smaller area than Arroyo Mocho, 2) the hills drained by Arroyo Las Positas (the Altamont Hills) tended to have a lower slope, and were thus less prone to erosion than the hills drained by Arroyo Mocho, and 3) the upland areas in each drainage were composed of different types of sediment. Unlike the hills to the south of Livermore-Amador Valley, which are made up of the coarse and erosive Franciscan Complex, the hills to the north are composed of the fine-grained Great Valley Sequence (Graymer et al. 1996). These differences in source geology were reflected in the soils of the valley floor. While coarse gravels dominated the large alluvial fans of the southern drainages, clay and silty soils with some alkali influence were found across the northern half of the Valley (Westover and Van Duyne 1911). Likely due to its low sediment supply, its low transport capacity, and the clay-dominated composition of its bed and banks, Arroyo Las Positas was historically and continues to be a single-threaded, tightly meandering channel.

Flows

The small, discontinuous streams draining the Altamont Hills helped create the alkaline conditions of eastern Livermore. These creeks carried salts from originating in marine sedimentary rocks, which then percolated into the groundwater and concentrated in the soils through high evaporation rates, creating the Springtown alkali sink (Trusk 1854 in Williams 1912, Westover and van Duyne 1911, Coats et al. 1988). Arroyo Las Positas historically re-formed downstream of the sink near Las Positas springs, and joined Altamont Creek near their present-day confluence. (The Las Positas springs were located just north of Interstate 580, east of Las Colinas Road.) Referred to as "Livermore's Creek" in early testimony, Arroyo Las Positas was named for the springs that fed it and maintained the creek as an important water supply in the otherwise dry eastern plain (Bryant [1848]1985). Early travelers and Gold Rush 49ers stopped at Las Positas and Livermore's rancho, as this was their last source of water before the San Joaquin River as they headed east (Moerenhout [1849]1935).

Immediately below Las Positas springs, the creek followed a confined path between two small knolls. A vegetated corridor, up to 130 feet (40 m) wide, likely consisted of a mix of willows and herbaceous vegetation (USDA 1940). Las Positas here was described in 1850 as "a shallow stream… supplying us with excellent water" (Ryan 1850). The creek appears to have followed several distinct courses over time, and was likely ditched to provide irrigation (see multiple channels in Thompson and West 1878, USGS 1907). Springs through this area along Las Positas were constricted between the hills and a thick clay cap (Williams 1912:49). As the City of Livermore developed, it initially relied on water from artesian springs in this area, although the water here was much more alkaline than that of the Pleasanton marsh complex (Williams 1912:227).

Some dry-season flow may have existed along Arroyo Las Positas near the Las Positas springs. Sherman Day described a "swampy water course" in July 1853 along Altamont Creek near Las Positas (1853). Surveyor Lewis recorded "running water" along a portion of the creek in summertime (1861:511).

Lower Arroyo Las Positas, below the springs and Altamont Creek, maintained a continuous single-threaded channel to the Pleasanton marsh complex. In contrast with the coarse gravels of Arroyo Mocho and Arroyo Del Valle, Las Positas flowed across a bed of comparatively fine sediment, skirting the edge of the wet and alkali meadows of central Livermore-Amador Valley. This contrast was of great importance to early engineers studying the Valley, because it meant that rather than providing groundwater recharge, Arroyo Las Positas functioned as a water transport system (Williams 1912, Fuller 1912). Cyril Williams described this contrast:

> The feeders of this artesian basin are the Arroyo Mocho and Valle Creeks; the other streams from the watershed, viz: the Positas, Tassajara, etc., traverse a territory where adobe and tight clay predominate, within and on the side of the channel, and on the surface of the surrounding country, with the result that the streams flowing over these, is continuous to the Laguna Creek, with no measurable loss into the gravels of the valley. (Williams 1912:31)

Flow data available from the USGS between 1912 and 1930 at Airway Boulevard illustrates the intermittent character of the stream, with an average of 92% of days per year without flow above 1 cfs in the 18 year period of record. Comparing that to data from the 1980s (which was a wetter time period, and gauged at a slightly different location on the stream), we see an average of only 17% of days per year with no flow above 1 cfs (Figure 3.19). We assume the difference in flow duration may not be due to the differing locations along the creek, but due to a combination of more rainfall, the increase in urban development, inputs from the South Bay Aqueduct, and perhaps tectonic shifts which activated springs (Stevens pers. comm.).

Riparian Vegetation

Riparian cover along Arroyo Las Positas (and the smaller tributaries) varied in width and composition as the stream flowed west. In the upper part of the watershed, the riparian vegetation was part of the larger alkali wetland. Alkali sink scrub and alkali meadow species bordered the creek, with iodine bush (*Allenrolfea occidentalis)* concentrated along the stream corridor (Burtt Davy 1898, Coats et al. 1988). As the creek flowed between the two bedrock knolls, groundwater came closer to the surface and artesian

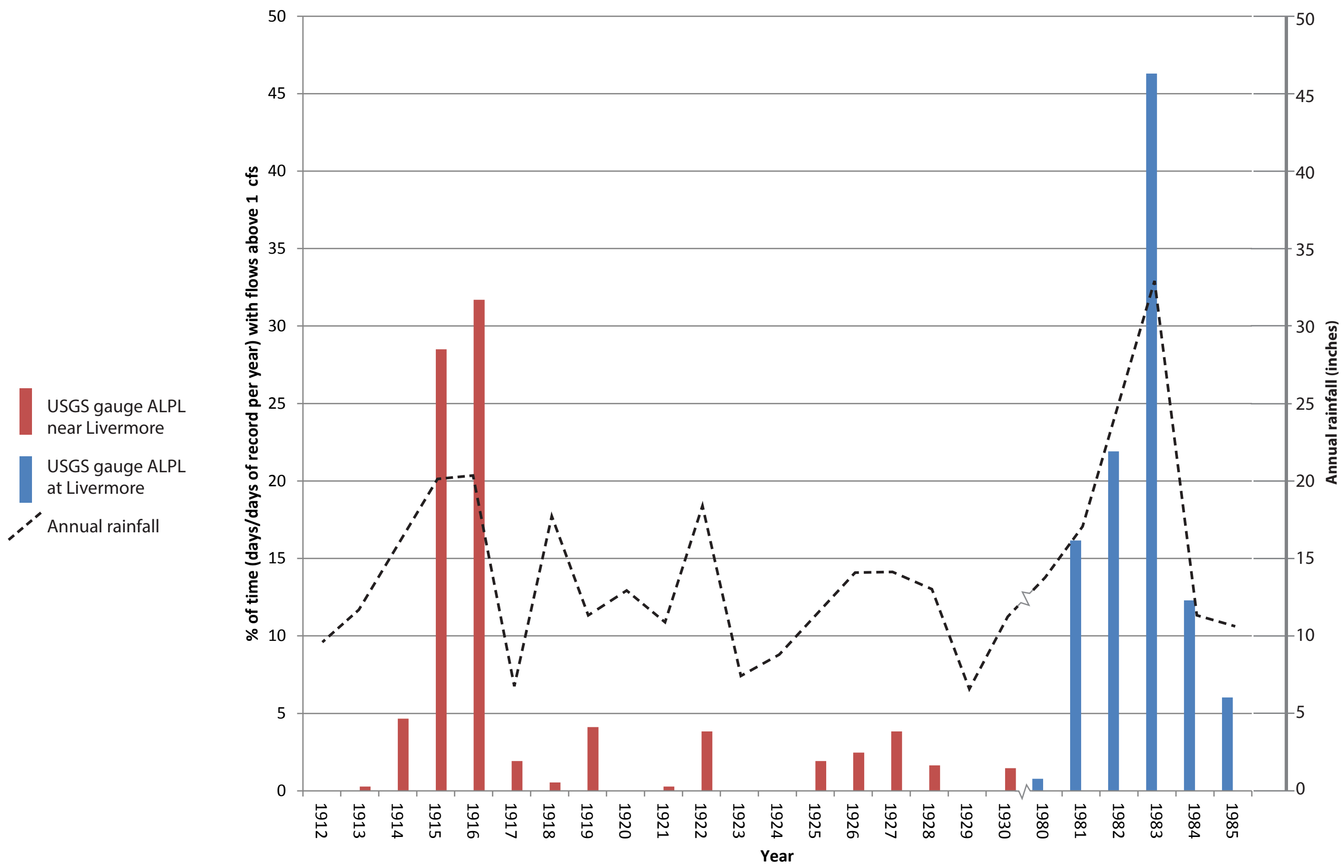


Figure. 3.19. USGS flow data from Arroyo Las Positas from 1912-1930, 1980-1985 displaying percent of time (days/year) with flows above 1 cfs in Arroyo Las Positas overlaid with annual rainfall data. In the first part of the 20th century flows were intermittent, and variable. Due to recent development, Delta inputs and perhaps tectonic shifting, the stream has become largely perennial. More data is necessary to fully confirm this hypothesis.

conditions developed (Williams 1912:49), supporting a vegetated corridor on the order of 100 feet wide (USDA 1940). This contrasts with the much wider, sycamore alluvial woodland-dominated braided channel of Arroyo Mocho at similar elevations.

Further downstream, historical sources suggest a relatively narrow riparian corridor, widening into patches of dense vegetation near springs or reaches with higher groundwater. Between these patches, riparian vegetation likely consisted of occasional oaks and herbaceous vegetation. However, even within this relatively unvegetated reach, there were patches of more dense riparian vegetation. Directly upstream of the confluence with Collier Creek, GLO surveyors noted crossing "a swampy water course" (Day 1853) in July, and oak trees lining the creek. Aerial photos from 1940 show several remnant swaths of willows 150-250 feet wide, indicating that even within this relatively sparsely vegetation reach, there was substantial variation (USDA 1940). These may have been anomalous reaches of rising or shallow groundwater, which enabled dense willows and other riparian vegetation to survive year round. The wetness of the soil may have made these areas unattractive to farmers, explaining why seasonal wetlands were still visible in the 1940s, at the height of agriculture in the Valley (Banke pers. comm.).

A conceptual framework for the historical patterns of topography, sediment, water, and vegetation on Arroyo Las Positas is shown in Figure 3.20. We present two case studies describing distinct reaches of this part of the stream, analyzing their historical function and change over time, and presenting conceptual scenarios for future management.

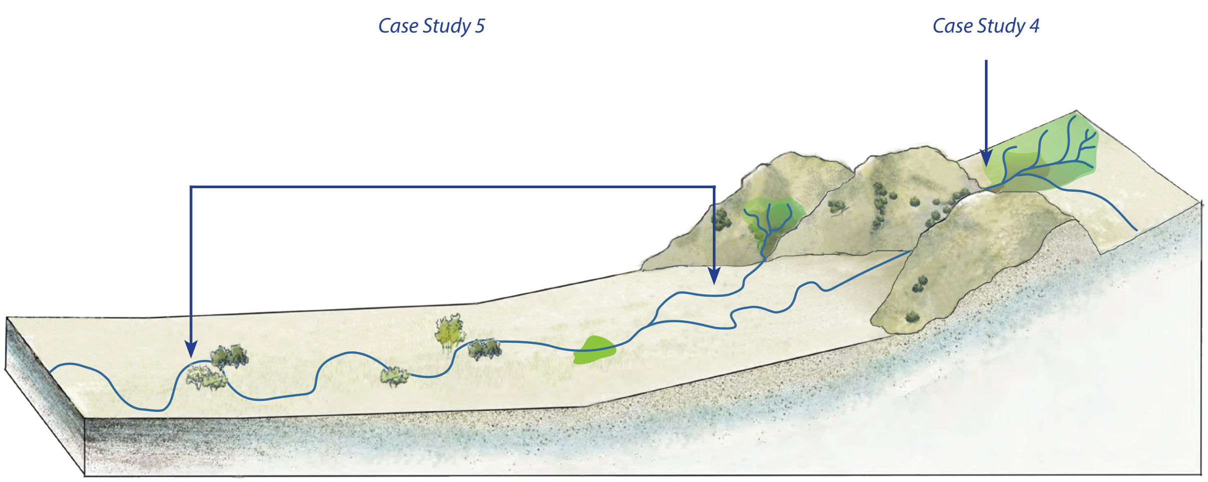
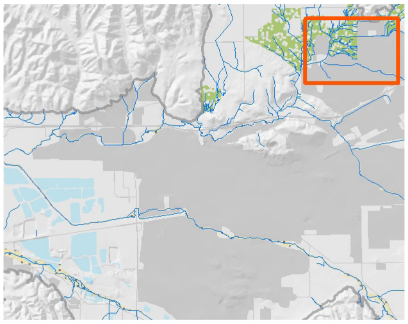


Figure 3.20. Conceptual model of historical Arroyo Las Positas, ca. 1800. This diagram shows a simplified oblique view of Arroyo Las Positas as it winds through the bedrock knolls (exaggerated) below Springtown, and across the northern part of the Valley. The green polygons indicate wetland areas of Springtown sink and an alkali area near Cayetano Creek. Some willow thickets were also present on the valley floor, supported by high groundwater.



CASE STUDY 4: SPRINGTOWN SINK
PRESERVATION OF REMAINING ALKALI WETLAND COMPLEX

PROBLEM STATEMENT

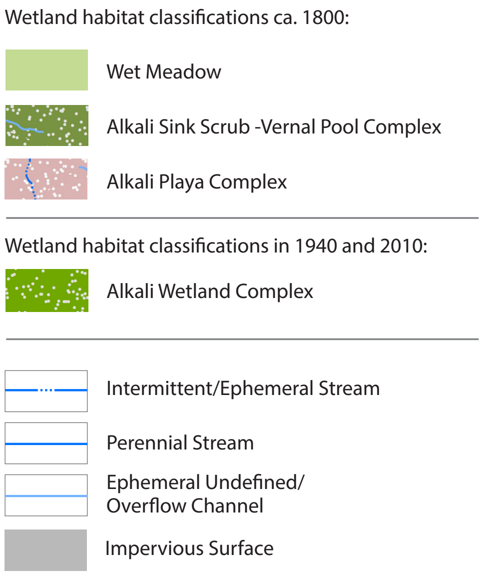
This case study encompasses the core of the historical Springtown alkali sink, extending approximately from present-day Dalton Avenue on the north to Wisteria Way on the south, and from Maralisa Court on the east to Monterey Drive on the west (Figure 3.21). The Springtown area once supported an extensive alkali sink wetland, extending up to 3,500 acres. Cattle grazing, off-road vehicle use, and the construction of residential subdivisions and the Springtown Golf Course in the 1960s and 70s have damaged or eliminated much of the original wetland (Coats et al. 1988:15). Channelization of Altamont Creek and other streams within the basin, combined with increases in urban runoff and other modifications to the flow regime, has resulted in channel incision and localized sedimentation problems (Zone 7 2006:3-19, Coats et al. 1993). These modifications are likely contributing to sedimentation and erosion problems downstream as well. Furthermore, the alkali-influenced complex habitat mosaic that made up the Springtown sink supported several types of rare and endangered plant and animal species that were historically common in parts of California but are becoming increasingly rare (Coats et al. 1993, Holland 2009, ICF International 2010).

UNDERLYING PHYSICAL AND ECOLOGICAL PROCESSES

Along with the Pleasanton marsh complex, the Springtown alkali sink was historically one of the main sites of surface water storage in the Livermore-Amador Valley. Composed of 3,500 acres of alkali wetlands east of Livermore, the sink formed in a small basin divided from the rest of the Valley by small bedrock protrusions and a fault (Springtown anticline and fault; Ferriz 2001, Sawyer and Unruh 2004, Unruh and Sundermann 2006). These barriers caused water to collect behind the hills and spread out, forming wetlands. Compact clay soils across much of the area also helped maintain the wetland by inhibiting drainage (Westover and Van Duyne 1911). A network of shallow, ephemeral streams flowed through the Springtown alkali sink.

The high alkalinity of the wetlands was derived from the marine sedimentary rocks in the surrounding watershed, which have a high salt content (Westover and Van Duyne 1911, Carpenter et al. 1984, Edwards and Thayer 2008, Mikesell et al. 2010). As these rocks eroded, water carried the salts downstream to the wetland, where they accumulated over time. This process resulted in extremely high concentrations of alkali salts (Coats et al. 1988, US DOE 2004). Alkali levels in this region were greater than 0.2% (in the first six feet), and ranged up to over 1% in some places (Westover and Van Duyne 1911). These salts percolated into the groundwater – one account described a well that was bored to 640 feet, only to produce water that "shot up through the well and rose to 40 feet above ground level…the water was strongly alkaline, and killed all vegetation in the vicinity" (Williams 1912:48).

While some accounts (such as the one above) note that the alkaline water "killed all vegetation," the alkali wetlands in fact supported several distinct habitat types and a unique assemblage of salt-adapted plant species. The center of the basin consisted of a mosaic of alkali playas – unvegetated areas with extremely high salt concentrations which formed seasonal ponds in the rainy season. Bordering this was an extensive complex of alkali meadow, alkali sink scrub, and vernal pools. Alkali meadow formed in seasonally flooded areas with poorly drained soils, and was dominated by species such as saltgrass



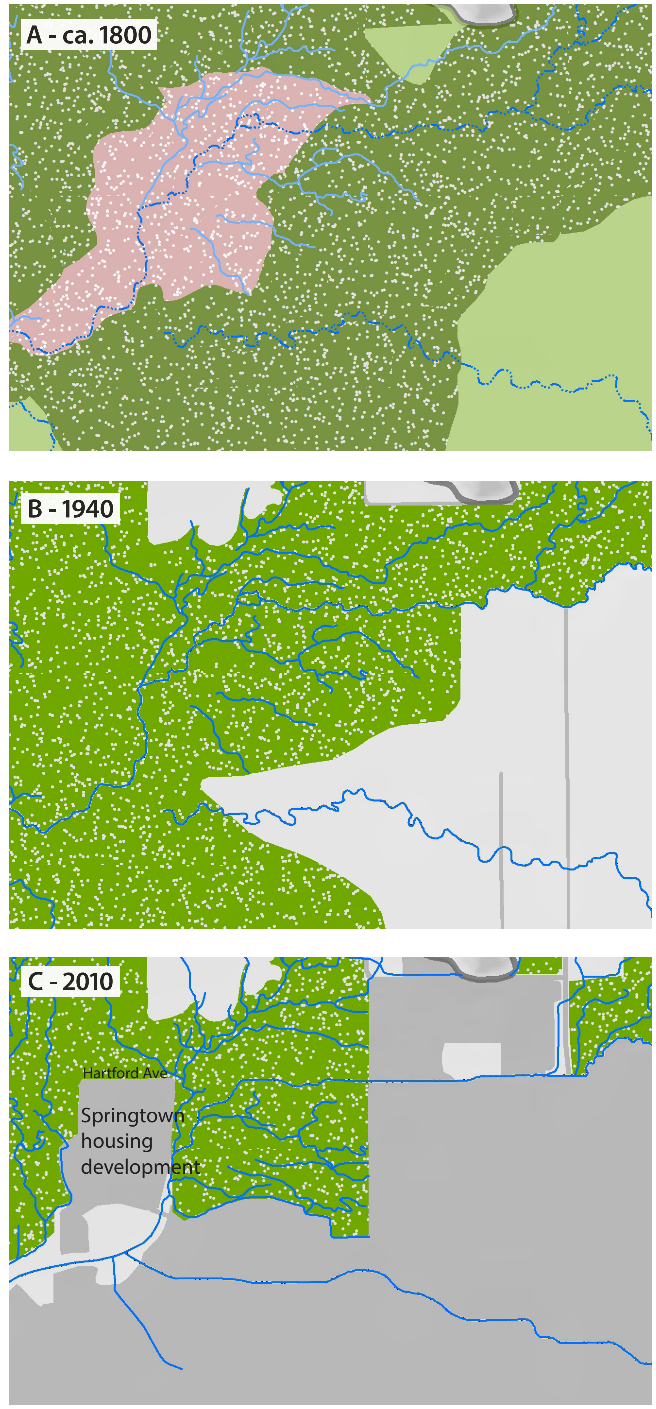


Figure 3.21. Changes in wetland habitat extent, stream configuration, and extent of impervious surfaces between 1800, 1940, and 2010 at the Springtown Sink. A. Historical conditions representing ca. 1800 (Stanford et al. 2013). B. Conditions in 1940 (USDA 1940, USGS 1942). C. Conditions in 2010 (USDA 2009, ICF International 2010, SFEI 2011).

(*Distichlis spicata*), alkali heath (*Frankenia salina*), and tidy tips (*Layia* spp.). Alkali sink scrub often occurred next to streams and alkali playas, and was dominated by shrub species such as iodine bush (*Allenrolfea occidentalis*) and seep weed (*Suaeda* spp.). Vernal pools were interspersed throughout the area, and supported specialized plants such as popcornflower (*Plagiobothrys* spp.) and downingia (*Downingia* spp.) (Goals Project 1999). Finally, at the eastern edge of the basin, Frick Lake (which shows up on maps as early as 1857) was a seasonal alkali lake or playa, drying in summer. The lake had no outlet historically, so alkali salts draining from the adjacent hills would have concentrated here over time. This lake exists in relatively unchanged form today (Kohlman et al. 2008). The range of habitat types – alkali lake/playas, sink scrub, vernal pools and alkali meadows – was organized along a gradient but also frequently intermixed, resulting in a diverse mosaic of species. Many small mounds, depressions, and swales formed the land surface, creating micro-scale variation in alkali concentrations and inundation frequency.

HISTORY OF CHANGES OVER TIME

The vernal pools in the Springtown alkali sink represent the most intact remnants of a large alkali wetland complex extending from Byron Hot Springs to the Mount Hamilton Range (Keeler-Wolf et al. 1998). Holland (2009) reported a 27% decline in vernal pool area in the Springtown complex between 1986 and 2005. However, the full historical extent was much greater.

The Springtown alkali sink remained largely undeveloped from the historical period to 1968. Early USDA aerial photography shows scalds and mounding characteristic of a vernal pool alkali wetland complex (Figure 3.22). While agricultural land uses dominated the surrounding landscape, the alkali soils at Springtown may have discouraged efforts at farming. The area was grazed however, leading to soil compaction (Coats et al. 1993). Construction of subdivisions commenced in 1968, and in the past 45 years residential development has significantly reduced and fragmented wetland habitats at Springtown (Coats et al. 1988; Table 3.3). This development has apparently been designed with little consideration given to the ecological impacts to the wetland: rather than expanding incrementally along the edges of the wetland, early subdivisions were constructed at multiple locations within the interior of the wetland, resulting in a higher degree of habitat fragmentation (see Figure 3.21 a-c).

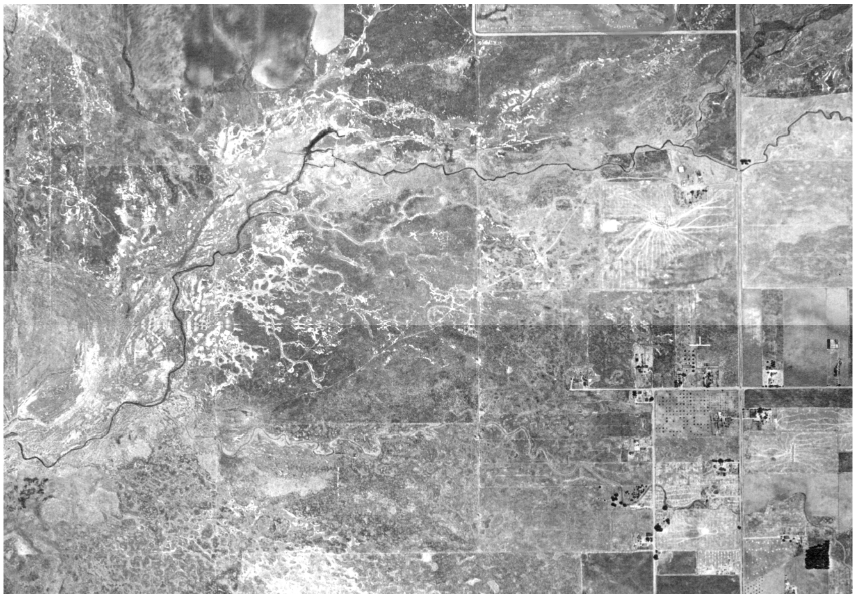


Figure. 3.22. Characteristic scalding patterns and mounds of vernal pool alkali wetland complex. The complex pattern of scalds (low, unvegetated areas of salt accumulation) and mounds (shown as small lighter areas) is characteristic of alkaline soils and vernal pool complexes (Coats et al. 1993).

Table 3.3. Undeveloped wetland acreage within Springtown sink over time.

	Springtown Alkali Wetland Acreage within Area of Interest	Percent remaining (%)
1800s	2,252.9	100
1940s	1,513.9	67
2009	875.75	39

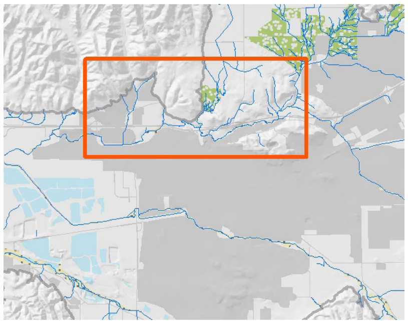
Urban development has been accompanied by a range of hydrologic modifications. In the 1970s, portions of Altamont Creek were channelized and numerous other drainages were diverted and extended to make way for subdivisions and to quickly convey water through the basin. Channelization and increased channel connectivity has resulted in increased erosion and decreased flooding within the basin. Channel density has increased through the remaining wetland complex from 4.49 miles/mile^2 in 1800 to 11.52 miles/mile^2 in 2009, reflecting the trend towards increased channelization. However, seasonal flooding still occurs within the Springtown wetland, as the physical drivers that formed the wetland (hills, faults, groundwater) are still relatively intact, but the frequency and extent of flooding is likely substantially less than what occurred historically (Coats et al. 1993:116,123).

FUTURE POTENTIAL

The Springtown alkali sink still supports significant remnants of several alkali-influenced habitat types, including alkali playas and scalds, alkali meadow, alkali sink-scrub, and vernal pool complex. Numerous rare and threatened plant and animal species occur within these remnant habitats, such as vernal pool fairy shrimp (*Branchinexta lynchi)*, California tiger salamander *(Ambystoma californiense),* Livermore tarplant *(Deinandra bacigalupii),* and the state and federally endangered palmate-bracted bird's beak *(Cordylanthus palmatus)* (Friends of Springtown Preserve n.d.). The ecological importance of the wetland has been recognized for some time, and approximately 51 acres are now protected within the Springtown Preserve operated by the California Department of Fish and Wildlife. Much of the wetland is still unprotected, however, and is threatened by development or degradation. Development would not only result in further habitat loss, but the additional hydrologic modifications that would likely accompany further development could also exacerbate watershed management problems. In the short term, we recommend that steps be taken to preserve and restore the remaining unprotected areas of alkali sink habitat in the Springtown area, as well as the hillslopes of the contributing watershed.

In the long term, Low Impact Development (LID) strategies in the Springtown area, and throughout the Valley, may be important to protect the remaining areas of the alkali sink and to address watershed management problems. LID refers to a suite of approaches and technologies designed to manage stormwater and reduce the environmental "footprint" of developed spaces. Examples of LID approaches include biofiltration devices or structures such as rain gardens, bioswales, and filter strips, as well as urban planning strategies that take into account natural hydrologic processes and endeavor to "design with nature" (Dietz 2007; Elliott and Trowsdale 2007). LID strategies could help to reduce channel incision and sedimentation in the Springtown area, transport of pollutants, and channel erosion in downstream reaches of Arroyo Las Positas. These strategies must be modeled to assess their effectiveness in poor drainage areas.

The Springtown sink has in some ways been irrevocably modified, but it also retains significant function. As evidenced by the persistence of alkali-influenced habitat types, the mounds and scalds, and the seasonal flooding patterns, the underlying hydrogeomorphology remains sufficiently intact to support the wetland. Preservation and enhancement of this complex is a significant opportunity for the long term ecological and hydrological functions of the Valley.



CASE STUDY 5: ARROYO LAS POSITAS
OFF-CHANNEL HABITAT OPPORTUNITIES

PROBLEM STATEMENT

The final case study encompasses a large area of Arroyo Las Positas downstream from Springtown, below the bedrock knolls. The boundaries extend approximately from Springtown on the east to the Las Positas Golf Course on the west (Figure 3.23).

Channel incision is currently occurring along Arroyo Las Positas from the edge of Springtown to the I-580 crossing approximately 0.5 miles east of Livermore Municipal Airport (Zone 7 2006:3-18). The incision is likely caused in large part by expansion of impermeable surfaces upstream (discussed in Case Study 4), artificial increases in streamflows from the State Water Project (SWP) water, and golf course irrigation causing an imbalance of water and sediment. The degree of channel incision is especially great between North Livermore Avenue and Portola Avenue, where the channel is as much as several meters below the valley bottom.

Further downstream, sedimentation is occurring along Arroyo Las Positas at the I-580 and Airway Boulevard bridges (Zone 7 2006:3-21 to 3-22). One consequence of this sedimentation is increased flooding risk due to decreased channel capacity.

Finally, a privately-owned remnant patch of vernal pool habitat exists along Cayetano Creek, approximately 1/3 mile upstream of the confluence with Arroyo Las Positas (Figure 3.24). Despite its high conservation value, this area is unprotected and at risk from development.

UNDERLYING PHYSICAL AND ECOLOGICAL PROCESSES

Unlike the valley reaches of Arroyo Mocho, which provided significant groundwater recharge, most of the water flowing through Arroyo Las Positas historically was conveyed as surface flow further downstream. The relative importance of groundwater recharge and surface transport in these different systems was largely determined by soil type: the coarse, gravelly soils along Arroyo Mocho and other streams in the southern portion of the Valley enabled surface water to percolate rapidly into the groundwater, while the fine-grained soils along Arroyo Las Positas inhibited groundwater recharge and promoted surface flow. The sediment dynamics of Arroyo Las Positas also differed markedly from those of Arroyo Mocho. While Arroyo Mocho deposited much of its comparatively coarse sediment load at the upper end of its alluvial fan, Arroyo Las Positas transported its finer sediment load further downstream. Water and sediment flowing through Arroyo Las Positas eventually entered the Pleasanton marsh complex in the western portion of the Valley (see Figure 2.3). Arroyo Las Positas was characterized by a single-threaded channel across the Valley. The low stream power and fine sediment load of Arroyo Las Positas (relative to Arroyo Mocho) precluded the formation of a large alluvial fan or extensive braided reaches as on Mocho. Flows were intermittent, with the exception of a short reach downstream of Las Positas springs (near present-day Las Colinas Road) (Stanford et al. 2013).

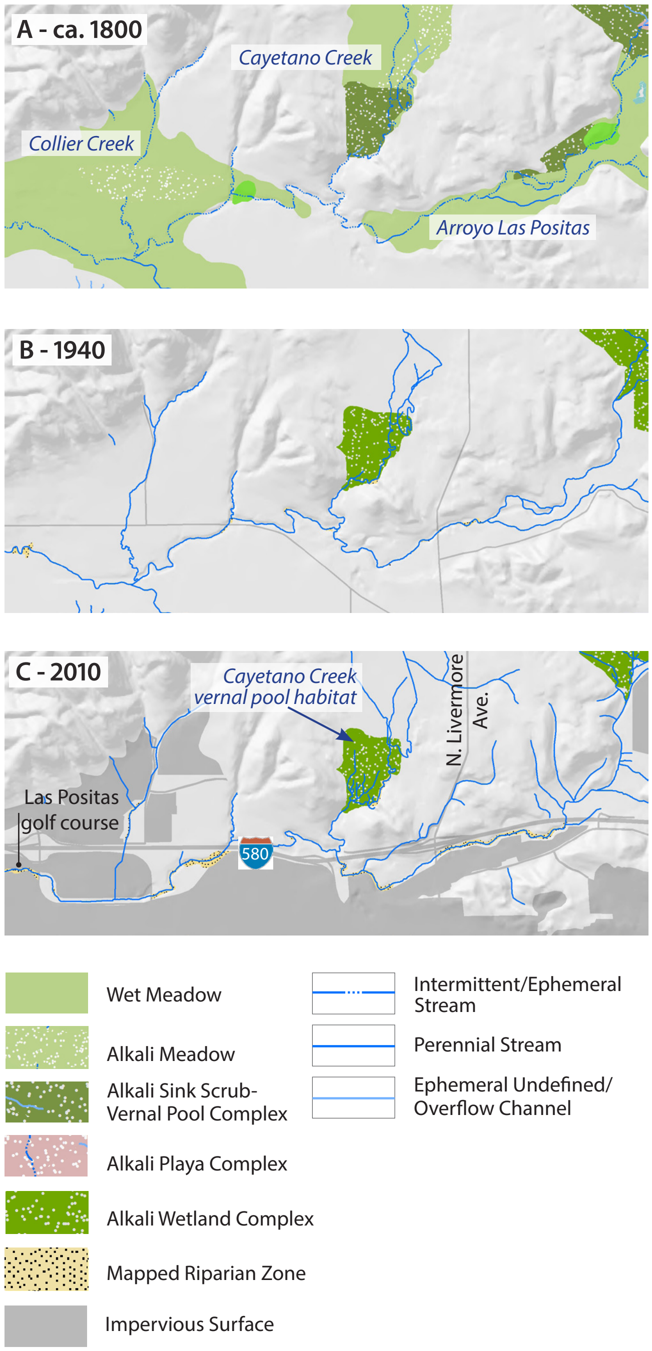


Figure 3.23. Change over time in riparian habitat extent, stream configuration, and extent of impervious surfaces between 1800, 1940, and 2010 on Arroyo Las Positas A. Historical conditions representing ca. 1800 (Stanford et al. 2013). B. Conditions in 1940 (USDA 1940, USGS 1940). C. Conditions in 2010 (USDA 2009, ICF International 2010, SFEI 2011).

For the most part, riparian cover along this reach of Arroyo Las Positas was herbaceous, with occasional oaks. Patches of denser cover, often dominated by willows, occurred less frequently, likely in areas of shallow groundwater (Stanford et al. 2013). Further downstream near Isabel Avenue, the riparian cover was likely dominated by grassland, occasional oaks, and seasonal wet meadow, which was inundated during the wet season but dry during the summer. Since the boundary of the Pleasanton marsh complex varied greatly on a seasonal and interannual basis, at times seasonal wet meadow may have extended as far east as this reach.

HISTORY OF CHANGES OVER TIME

A variety of factors have increased streamflow in Las Positas in recent decades, including the addition of SWP water, ditched connections between northern tributaries and Arroyo Las Positas, urban runoff, and irrigation at Springtown Golf Course. Tectonic movement along a fault in the eastern basin may also have contributed to increased streamflow (Stevens pers. comm.). Consequently, flow is now perennial in Arroyo Las Positas downstream of the Springtown area.

Extensive urbanization has occurred in this area, and along much of this reach Arroyo Las Positas is now bordered by roads, highways (I-580), shopping centers, or other urban development. Much of this development has occurred quite recently. For example, in 1993, much of the area between I-580 and Las Positas Road was still undeveloped (Figure 3.25). The increase in impervious surfaces and surface runoff associated with this widespread urban development has likely contributed to increased streamflow in Las Positas.

Changes in channel planform have also likely impacted stream functioning and contributed to sedimentation

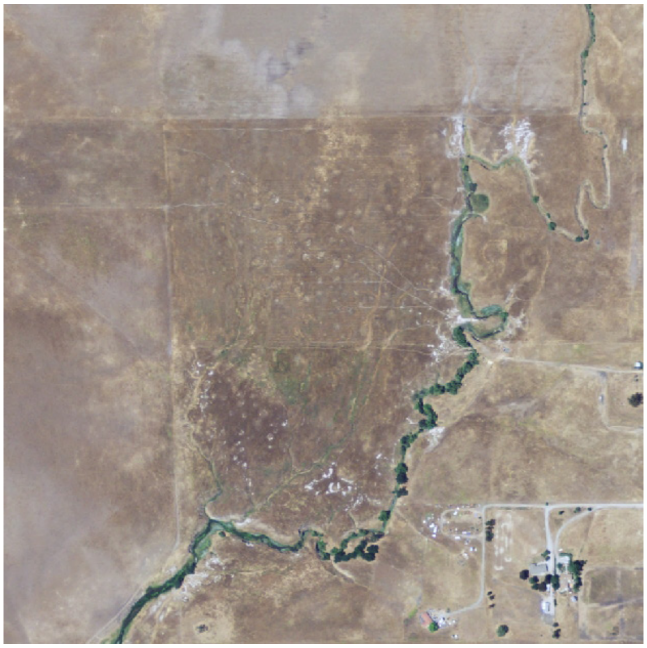


Figure 3.24. Remnant vernal pool complex near Cayetano Creek. The vernal pools can be identified by a mottled pattern of pools, swales, and mounds visible in the aerial photograph, and their presence was confirmed by local experts (Bartosh pers. comm).

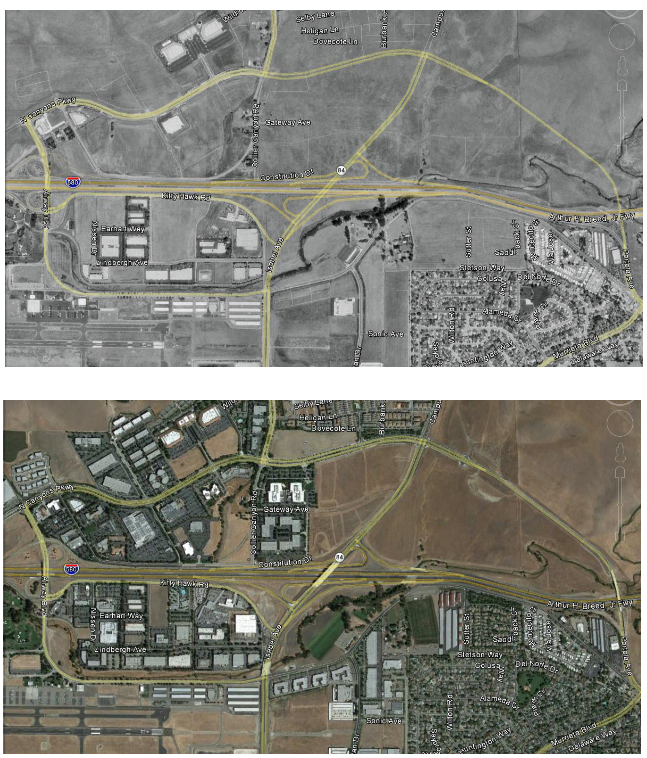


Figure 3.25. Comparison of Isabel Avenue area development between 1993 (top) and 2010 (bottom) showing rapid urbanization throughout the 1990s and 2000s in the northern hills above Arroyo Las Positas. (Google Earth 1993, 2010)

and channel incision. A comparison of USGS topographic quads shows that much of this reach of Arroyo Las Positas was straightened and channelized between 1961 and 1980. Channel straightening tends to increase bed slope by decreasing channel length, and thus leads to increases in flow velocities, which increases shear stress on the bed and banks and can lead to channel incision and widening in weakened areas (Booth 1990). In addition, tributaries such as Collier Creek, which were once discontinuous, have been straightened and extended to connect with the main stem (see Figure 3.23). These connections increase flows in the main stem and may have contributed to downstream incision and erosional patterns.

FUTURE POTENTIAL

Floodplain creation at strategic locations along Arroyo Las Positas could help to alleviate local channel incision and sedimentation occurring at the I-580 and Airway Boulevard crossings. Although sediment storage was not the primary function provided by this stream system historically, channelization, increased streamflow, and road construction have created a need for greater sediment storage capacity along this reach. Potential sites that might be considered for floodplain restoration include the undeveloped parcel just southeast of the Airway Boulevard crossing, the undeveloped parcel just east of the I-580 crossing, and the parcel between the I-580 and Isabel Avenue crossings (Figure 3.26).

Surprisingly, amidst the quick expansion of urban development in this portion of the Valley and the surrounding hills, an area of high quality vernal pool habitat has been left undeveloped and unplanted along Cayetano Creek (see Figure 3.24). Vernal pool habitats are increasingly rare

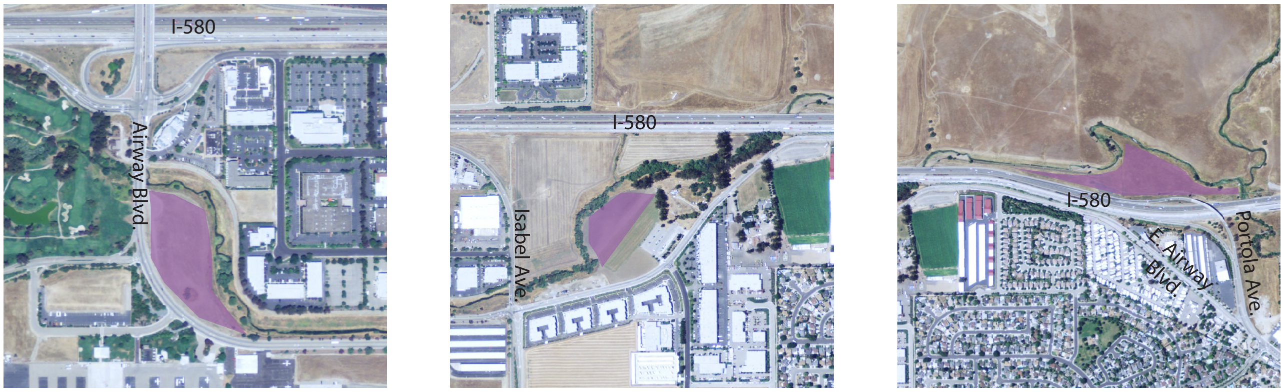


Figure 3.26. Potential locations for new surface water storage, and inset floodplain habitat (in purple). These sites on the valley floor need to be evaluated for land ownership, slope, and contaminants, but are some of the rare creekside open space still remaining that could be conserved for sediment retention or wetlands to mimic historical wet meadow/willow grove floodplain functions. These sites would need to be excavated down to allow for reconnection to the channel, and thus re-use of the removed dirt will need to be evaluated. These sites are also not the only potential places for inset floodplains on Arroyo Las Positas, and other sites should be evaluated as well. (USDA 2009)

in California: Holland (2009:1) states that within the Great Valley (defined as an 18,000,000 acre area encompassing 30 counties within California, including Alameda), approximately 87% of the pre-agricultural vernal pool complex habitat had been lost by 1997. Within Alameda County, the extent of vernal pool complex decreased by 27.1% between 1986 and 2005 alone (Holland 2009:8). The patch of vernal pool complex along Cayetano Creek is identified as a "key parcel for the protection of biological resources" in the North Livermore Plan Area in the North Livermore Priority Landscape Area Resources Conservation Plan Public Review Draft (Nomad Ecology 2008:135).

Conceptual Models of Arroyo Las Positas Evolution

The case studies isolated for this reach of Arroyo Las Positas are presented as separated sites, but are meant to be taken as a group, and analyzed cumulatively to assess multiple benefits for watershed management. Individually, these actions may have limited local benefit, but taken together they may increase ecological function and improve flood management over the course of the stream and watershed. We use an understanding of historical and current conditions to create a conceptual model of change over time, envisioning a future scenario that builds on historical functions and modern constraints (Figure 3.27). These three oblique views of Arroyo Las Positas are shown conceptually over three time periods: the historical period, the current day conditions, and projecting into the future based on the analyses done in the case studies presented above. Below each graphic, we present gradients of different important physical and ecological controls on the system: seasonality of water flow, type of water transport (recharge or transport, or both), sediment dynamics, and the state of riparian habitat. While many of the underlying physical parameters have stayed the same, these surface expressions of water, sediment and vegetation have vastly changed, and thus provide a window into reconstruction of historical functions back onto the landscape. On Arroyo Las Positas, many of our recommendations are simply to encourage protection of rare wetland areas. The recommended placements of inset floodplains are conceptual: actual floodplain restoration will require a better understanding of land ownership and site drainage, and will require hydraulic modeling to assess the flood storage benefits gained by several small floodplains. Finally, the results of these case studies are meant to be taken as a group, or as a vision for this reach of Arroyo Las Positas. Individually, these actions may increase habitat function, and decrease management problems, but the goal of these conceptual models is to envision the stream as a unit, and to plan cumulative restoration projects and management actions that together add up to a healthier watershed.

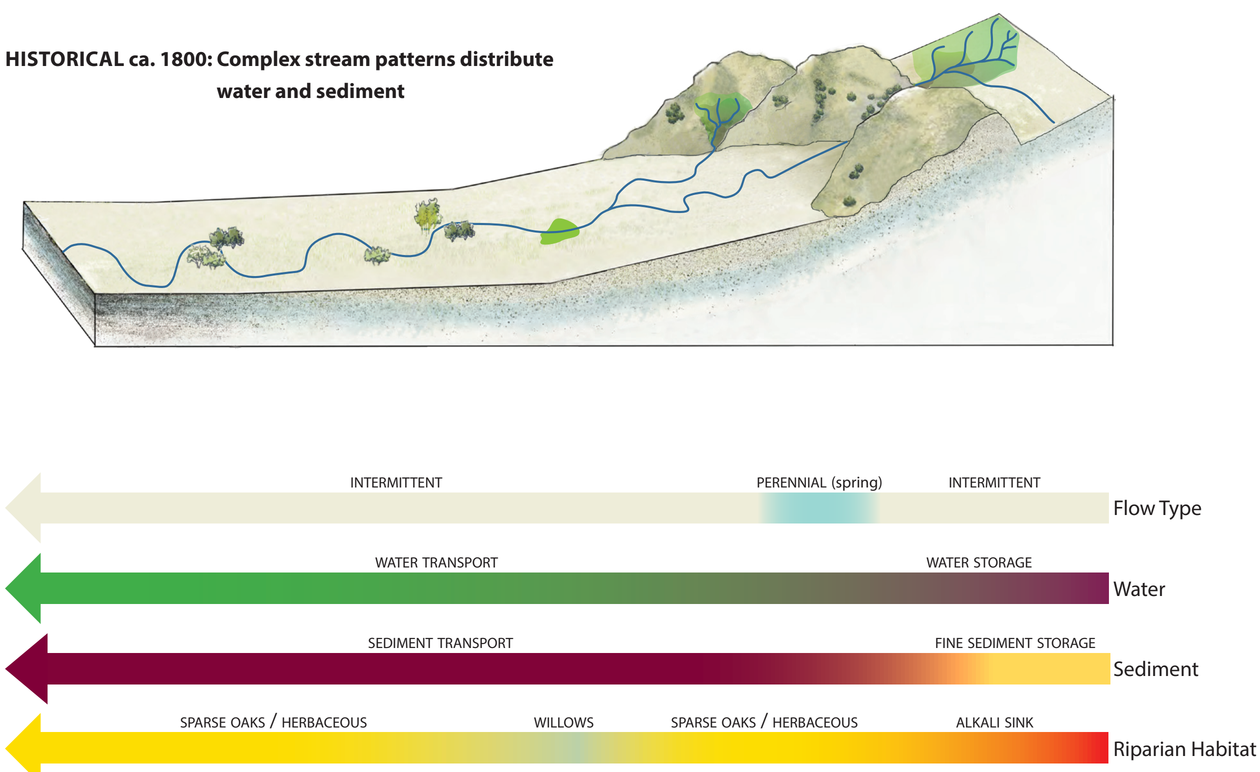
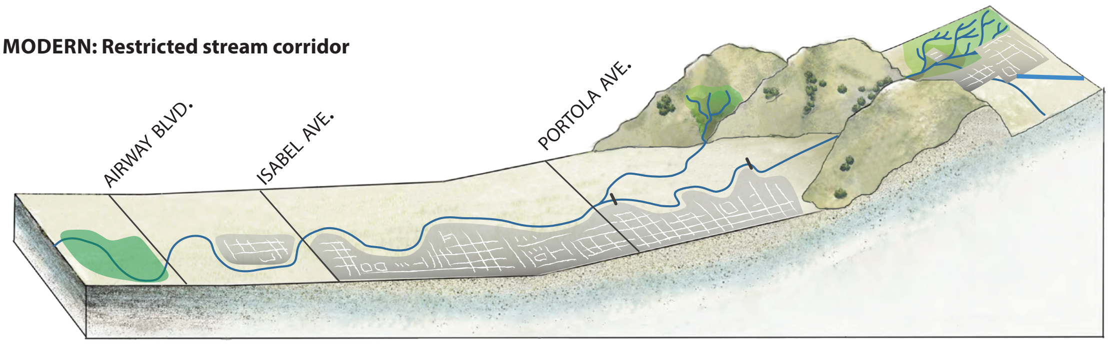
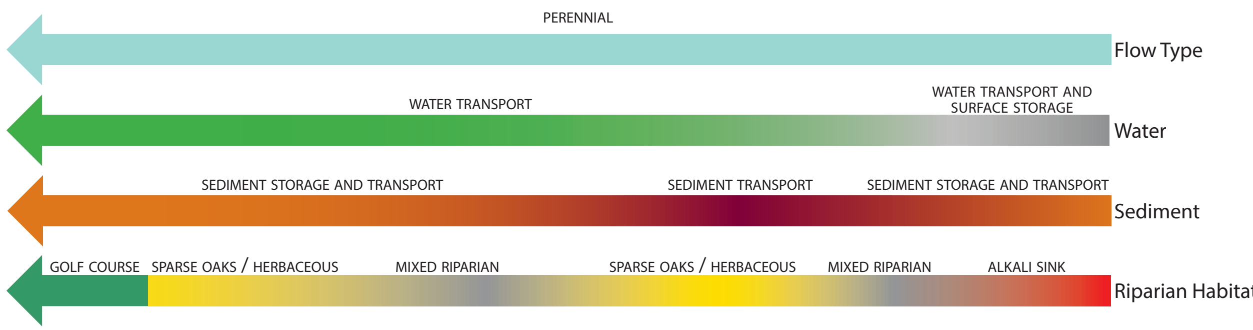


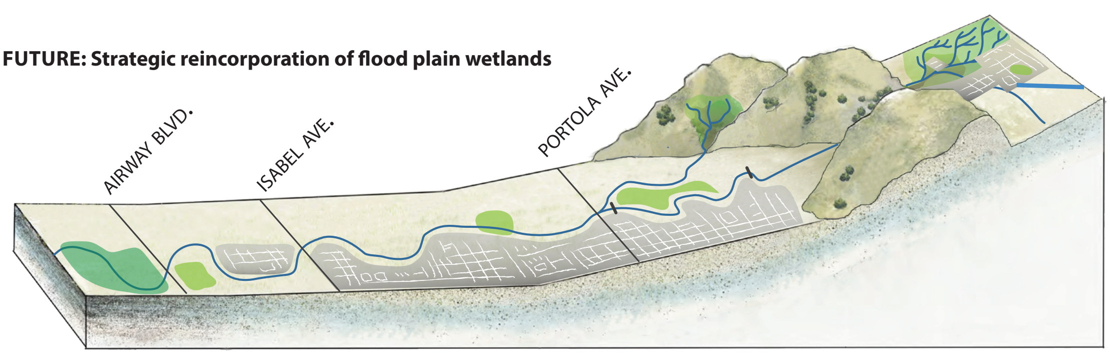
Figure 3. 27. Past, present and future conceptual models of Arroyo Las Positas from Springtown to Las Positas Golf Course.

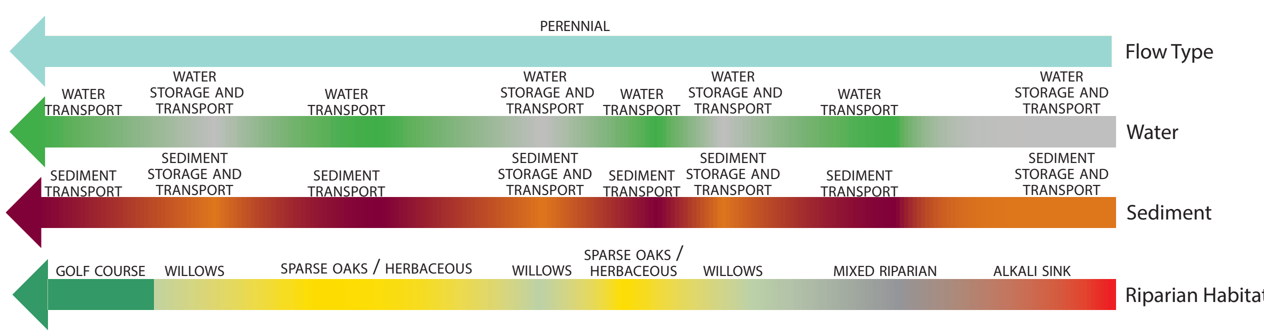
MODERN: Restricted stream corridor





FUTURE: Strategic reincorporation of flood plain wetlands





4. CONCLUSIONS

Summary of recommendations and next steps

This analysis provides a first step in developing a landscape-scale strategy for addressing multiple challenges and goals in the Zone 7 service area. We first outline a process-based framework for identifying the underlying physical and ecological processes shaping different parts of the system. We then evaluate landscape scale changes and existing potential for modifications to address contemporary challenges. These represent an initial exploration of concepts. Next steps would involve further refinement of a larger vision in concert with Zone 7 staff and additional technical analysis.

This type of assessment, though essential, is often missing from the planning process. Short term projects often move forward without sufficient consideration of how and where they fit into the watershed, or what the cumulative impacts may be of many projects over time. Table 4.1 summarizes the main restoration actions guided by watershed processes, and proposed by this report, listing them as either short term, long term, or both. Next steps may include putting combinations of these proposals together to assess cumulative short and long term benefits that could be gained.

Table 4.1. Short term and long term interventions as opportunities for increased ecosystem function at a watershed scale

Stream	Reach	Intervention	Timescale	Functions
Arroyo Mocho	Southeast	Restore braiding when agricultural land is sold	Long term	Increased sediment deposition and in channel storage, sycamore alluvial woodland
	Holmes Street Bridge to Madeiros Parkway	Restore braiding in parkland	Short term	Increased sediment deposition and in channel storage in parks, decreased sedimentation at Holmes Street Bridge and Stanley Boulevard Bridge, increased diversity in riparian habitat
	Distributaries	Addition of channels to act as distributaries into gravel pits, reconnection of floodplain habitat to channel	Short term and long term	Sediment transport into gravel pits at high flows, reconnection of floodplains, re-introduction of native species
Arroyo Las Positas	Springtown	Preserve remaining vernal pool habitat, discourage development	Short and long term	Important habitat for rare and endangered species, flood attenuation (sink), natural LID
	Cayetano vernal pools	Preserve remaining vernal pool habitat, discourage development	Short and long term	Important habitat for rare and endangered species, flood attenuation (sink), natural LID
	I-580 corridor	Lower floodplain areas to create off channel habitat	Long term	Mimicking wet meadows, LID functions, decreasing impacts of incision (lowering adjacent floodplains), flood attenuation

Long term planning considerations

For practical reasons, streams are often managed in discrete reaches or according to property lines, responding case by case to bank failures or other incidents. However, it behooves managers, planners, and scientists alike to scale up and evaluate the cumulative effects and impacts of restoration efforts and stream management interventions, developing longer term visions to manage at a watershed scale. Historical ecology helps to arrive at that vision, revealing the underlying geologic, geomorphic and hydrologic gradients and processes that are not easily altered, as well as those processes that have changed irrevocably (such as surface and groundwater hydrology, land cover, etc.). A successful vision for a watershed approach to restoration and beneficial management relies on a deep understanding of natural landscape patterns and processes and the degree to which they have changed or remain intact or recoverable.

The site scale actions proposed in this report can be undertaken separately, but if implemented together they have the potential to have a much greater cumulative impact. For example, high sedimentation rates along Arroyo Mocho (which has the highest sediment supply of any stream in the Valley) have necessitated regular sediment removal, which is a costly, ongoing management solution. Interventions on Arroyo Mocho, such as restoring floodplains and braided channel morphology throughout the upper part of the study area (Case Studies 1 and 2), would allow for more naturally-organized in-channel storage along a substantial reach, and would likely lessen sediment delivery to downstream Zone 7 facilities. Further study is needed, including modeling of cumulative impacts of flood retention and sediment transport when combining these components. Determining targets for peak flow reduction and sediment deposition and the costs associated for each scenarios may be effective next steps.

Individual floodplains added to the Arroyo Las Positas stream network may not make a large difference for flood control, but the cumulative effects may include slowing stormwater flows, increasing off-channel sediment storage, and discouraging more development in the Valley. Similarly, maintaining individual wetland habitat patches may not increase populations of particular rare and endangered species, but protecting a network of wetland habitats across the landscape may enhance ecological connectivity and function. Furthermore, wetlands provide surface storage for storm flows - nature's LID.

Although urbanization has irrevocably transformed the Valley and modified hydrologic processes, practical strategies exist to minimize the detrimental impacts of urban development on stream networks and riparian habitats. Greater implementation of LID practices in strategic places to mimic historical stream and watershed function and distribution may help to ameliorate a number of stream management problems in the Valley.

Urbanization has also affected the quality and habitat value of riparian vegetation throughout the Valley. Just along Arroyo Mocho, riparian vegetation ranges from a relatively intact riparian corridor with oak and sycamore near Robertson Park and Madeiros Parkway to highly disturbed non-native grassland and eucalyptus stands west of Stanley Blvd. While we encourage efforts to restore riparian habitats within the Valley, it is important to recognize that the structure and composition of these habitats is controlled by a variety of physical factors that operate at multiple scales. In order to be successful, restoration efforts must take these constraints into account. To the degree possible, efforts should address management problems by working to restore the underlying physical drivers as a way to recruit desired native riparian habitat.

Parrott and Meyer (2012) urge managers to "take advantage of [a] systems's internal memory" - in other words, to restore or mimic the processes and disturbance regimes under which a landscape or ecosystem evolved. In some cases, a system's internal memory may be literally visible - for example, the imprint of past terraces visible in LiDAR scans. It is also useful to assess to what degree a system has retained this internal memory. Which processes that shaped the system historically are still active today? Which have been altered or eliminated? Where have legacy features persisted, and how do these constrain the potential of a particular site?

Trying to reconstruct historical components back onto a landscape is unrealistic, and yet throwing out all historical reference to create 'novel' ecosystems may be equally ineffective (Hobbs et al. 2009, Jackson and Hobbs 2009). Historical legacies set the course for conceptual approaches for designing more resilient systems in the future. Not all "fixes," designs, or landscape-level restoration projects can be completed at once, or even in a short time frame. Yet having the vision for a resilient landscape allows managers to put the "pieces of the puzzle" together in a way that is forward thinking, cumulative, multi-beneficial, and economically prudent, letting nature do the work.

Recommended actions for next steps

- Set measurable goals (e.g., percent reduction in the frequency of sediment removal, percent flow reduction for specific stream reaches) to guide progress towards the design of a more resilient channels that provide multiple benefits and support desired ecosystem functions.
- Further refine proposed conceptual solutions to define specific project locations and management actions, and conduct site inventories as needed
- Model cumulative effects of proposed conceptual projects to identify the most cost-effective approaches for reaching management goals
- Integrate approaches with SMMP development and prioritize next steps

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APPENDIX A: METHODS

Several of the methods used in this report incorporated information from the Alameda Creek Historical Ecology Report (Stanford et al. 2013). We synthesized this historical data and added contemporary information to examine physical gradients and drivers; analyze hydro-geomorphologic, ecological, and land use changes over time; devise landscape-level restoration/intervention strategies; and develop conceptual models illustrating potential landscape scale trajectories. This involved compiling SFEI studies examining sediment dynamics in the watershed, conducting SFEI riparian vegetation surveys, compiling Zone 7 reports and the currently-in-revision Zone 7 Stream Management Master Plan (SMMP), gaining local expertise from Zone 7 staff, utilizing USGS topographic quadrangles, aerial photographs, and a variety of other reports and data inputs.

Several new GIS data layers were developed for this project in order to assess interim time periods and evaluate change over time, focusing on impervious surfaces, road networks, and riparian vegetation extent.

GIS LAYERS

GIS layers were developed to represent various aspects of the Valley's ecology, hydrogeomorphology, and land use at four time periods: 1800s, 1940s, 1980s, and 2009.

Channel network

The channel network data layers were created for each of the four time periods using data compiled from a variety of sources. For the 1800s, we used the channel network layer developed for the Alameda Creek Watershed Historical Ecology Study (Stanford et al. 2013). This layer was developed by modifying the Bay Area Aquatic Resource Inventory (BAARI; SFEI 2011) mapping where historical sources showed a clear divergence from modern sources. Historical sources used included 1940 aerial photographs (USDA 1940), historical USGS topographic quads, other early maps of the Valley, and GLO surveys.

The 1940s channel network layer was developed using the 1800s channel network layer as a starting point. The channel network was modified where necessary based on the 1940 aerial imagery. For the 1980s, we used the National Hydrography Dataset (NHD) Flowline data for the channel network layer (USGS 2005). For 2009, we used the BAARI mapping.

Gravel pits

Gravel pits data layers are only included for two time periods: 1980s and 2009. For the 1980s, we used the National Hydrography Dataset (NHD) Waterbodies layer to represent the gravel pits. For 2009, the gravel pits were digitized from the National Agriculture Imagery Program (NAIP) imagery (USDA 2009). Only gravel pits with a distinct boundary visible in the NAIP imagery were digitized. We compared the digitized gravel pits to existing maps of the Zone 7 service area.

Impervious surfaces

Impervious surfaces data layers were created for the 1940s, 1980s, and 2009, and include areas occupied by urban areas and major roads and highways. For the 1940s and 1980s, urban areas were mapped by modifying the 1940 and 1974 USGS San Francisco Bay Region Urban Dynamics Data Set layers (USGS n.d.) based on USGS topographic quads from the 1940s and 1980s, respectively (USGS 1940, 1942, 1980, 1981). For the 1940s, major roads and highways were digitized from 1940 aerial imagery, and a 15 m buffer was created around both roads and highways. For the 1980s, major roads and highways were digitized from the 1980s USGS quads, or where possible from the NAIP 2009 imagery using the 1980s USGS quad for interpretation. For 2009, major roads and highways were digitized from the NAIP 2009 imagery. For both the 1980s and 2009, a 20 m buffer was created around major roads and a 40 m buffer was created around highways.

Riparian vegetation

We created riparian vegetation data layers for the 1800s, 1940s, and 2009. Areas classified as riparian include both wooded and sparsely-vegetated areas within or adjacent to the stream channel.

The 1800s riparian vegetation layer includes riparian land cover types from the Alameda Creek Watershed Historical Ecology Study habitat mapping (Stanford et al. 2013). For our area of interest, these include Sparsely Vegetated Braided Channel, Sycamore Alluvial Woodland, Pond, Valley Freshwater Marsh, and Willow Thicket. For areas along Arroyo Mocho where riparian vegetation was not mapped in the historical ecology report, we used a 130-m wide riparian corridor which had been previously mapped as the 'active channel'. The layer also includes non-riparian wetland habitats from the Alameda HE study habitat mapping, including Alkali Meadow, Alkali Sink Scrub-Vernal Pool Complex, Alkali Playa Complex, and Wet Meadow.

The 1940s riparian vegetation layer was digitized from the USDA 1940 aerial imagery. For the 2009 riparian vegetation layer, we started with the ICF riparian vegetation mapping (ICF International 2010) and modified the boundaries based on NAIP 2009 imagery. Within our area of interest, ICF riparian vegetation types included Mixed Riparian Forest and Woodland and Mixed Willow Riparian Scrub. Where ICF did not map riparian vegetation, we created a 10-m riparian buffer along Arroyo Mocho, Arroyo Las Positas, Altamont Creek, and Arroyo Seco. For the 1940s and 2009 layers, we attributed the riparian corridor using a generic classification called Mapped Riparian Zone.

We also digitized wetland habitats in the Springtown area for 1940s and 2009 using the USDA 1940 imagery and NAIP 2009 imagery, respectively.

RIPARIAN WIDTH CLASS ANALYSIS: ARROYO MOCHO

We analyzed the change in riparian corridor width along the portion of Arroyo Mocho within our study area between the 1800s, 1940s, and 2009. For each time period, the riparian corridor was divided into three width classes: <60 m, 60-200 m, and 200-400 m. A division was created wherever a new width class started or ended, so that each segment of riparian corridor fell within a single width class. For each segment, the average width was estimated using the Measure tool in ArcMap. Stream reaches were coded with the width class and average width of the corresponding riparian corridor segment. We then calculated the proportion of total stream length for each width class for each time period.

RIPARIAN VEGETATION FIELD MAPPING METHODS

To obtain a better picture of the current condition of riparian habitats within the study area, we conducted vegetation surveys along a portion of Arroyo Mocho from Concannon Blvd to approximately ¾ mile west of Isabel Avenue. In GIS, we segmented the riparian areas into field polygons corresponding to three stream reaches ("Robertson Park," "Holmes," and "Stanley") and four geomorphic zones (channel, inner bench, outer bench, and floodplain). Within each field polygon, we counted the number of each tree species and recorded tree size class. For detailed information on our vegetation mapping methods and results, see Appendix B.

APPENDIX B. RIPARIAN MAPPING ON ARROYO MOCHO

INTRODUCTION

Ideally, restoration efforts are guided by an integrated understanding of regional historical ecology, landscape processes, and contemporary site-specific conditions. Combining insights from these varied perspectives provides a more comprehensive picture of restoration opportunities and constraints, and hopefully leads to more successful restoration outcomes. Within our study area, and particularly within the Arroyo Mocho case study areas, riparian habitats represent both important restoration targets as well as key drivers of hydrogeomorphic processes such as channel stabilization and groundwater recharge. Thus, in order to develop effective restoration strategies and to prioritize sites for possible management interventions along Arroyo Mocho, it was necessary to assess the current condition of riparian vegetation.

We conducted riparian vegetation surveys along the Arroyo Mocho corridor from Concannon Blvd to approximately ¾ mile west of Isabel Avenue. Surveys were conducted between November 1 and 15, 2012. The goals of the surveys were to provide further insight into the current condition of riparian vegetation within our case study areas, and to help identify priority areas for preservation or restoration. Information collected through the surveys was intended to help address the following specific questions:

1. What is the size distribution of riparian trees? Where have mature trees survived? Where are they regenerating?
2. How does the density of riparian vegetation vary by reach and geomorphic setting?
3. How does species dominance vary by reach and geomorphic setting?

Sycamores, as the dominant tree in what was once a widespread but is now a relatively uncommon riparian habitat type, were the focus of particular interest in our riparian mapping.

METHODS

Pre-field

In GIS, we segmented the riparian area into polygons corresponding to their reach and geomorphic zone. The survey area included three reaches: Robertson Park (from Concannon Boulevard to Arroyo Road), Holmes (from Arroyo Road to Holmes Street), and Stanley (from N Murrieta Boulevard to approximately ¾ mile west of Isabel Avenue).

Geomorphic zones were determined using aerial and LiDAR imagery, and included channel, inner bench, outer bench, and floodplain. The channel was defined as the area immediately surrounding the active channel up to the first distinct bench visible in LiDAR imagery. The inner bench was defined as the area extending from the channel to the next distinct change in elevation, and the outer bench was defined as the area extending from the inner bench to the boundary of the stream corridor (identified by a distinct topographic change or by the interface with developed urban areas). The floodplain geomorphic zone was assigned to two large polygons in the Holmes reach separated from the mainstem by a walking trail. The four geomorphic zones were further segmented into a series of field polygons small enough to sample within. Each field polygon was assigned a unique ID number. In some cases, the polygons were modified in the field to better represent geomorphic conditions on the ground.

Field

In the field, we visually established the extent of each field polygon on the ground using aerial photographs, and conducted vegetation surveys within each polygon sequentially. Within each field polygon, we attempted to count each tree and record species name and size class. We also noted the dominant understory species in each field polygon. In areas where the vegetation was too thick permit access or to allow counting of individual trees, we estimated tree abundance and size class. Recorded tree species included:

- Sandbar willow (Salix hindsiana)
- Willow species (Salix laevigata and/or Salix lasiolepis)
- Fremont cottonwood (Populus fremontii)
- California black walnut (Juglans hindsii)
- Western sycamore (Platanus racemosa)
- Valley oak (Quercus lobata)
- Coast live oak (Quercus agrifolia)
- Eucalyptus (Eucalyptus spp.)
- California buckeye (Aesculus californica)
- Tanbark oak (Lithocarpus densiflorus)
- Other

We classified each tree into one of four size classes, designated C1 through C4 (Figure B1). C1 was used to represent trees in the smallest size class, which included seedlings and small saplings. C2 included medium to large size saplings. C3 included small to medium-sized trees, and C4 was reserved for mature trees.

In addition to surveying riparian vegetation, we recorded the location of notable geomorphic features such as inactive side channels and gravel bars.

SOURCES OF ERROR

Our findings may have been affected by several sources of error. First, there were likely small (<5 m) discrepancies between the boundaries of the field polygons created in GIS and the boundaries of the field polygons identified on the ground; these discrepancies may have had a small impact on the number of trees counted for a given polygon. Second, portions of the field polygons where vegetation was especially dense were difficult to access, and in some cases trees in these areas had to be identified and counted from a distance. Third, in areas of especially high tree density, we were unable to count individual trees, and thus had to estimate tree abundance and size class. Fourth, although an effort was made to standardize size class definitions, tree size class was determined by visual estimate rather than direct measurement, and thus there was likely some inconsistency in how sizes classes were assigned. Finally, mulefat (Baccharis salicifolia) was inadvertently included in the counts of sandbar willow, artificially inflating estimates of willow density. To correct for this, sandbar willow counts on benches and floodplains in the Holmes and Robertson reaches were reduced by 75%, and counts in channels in the Stanley reach were reduced by 25%.

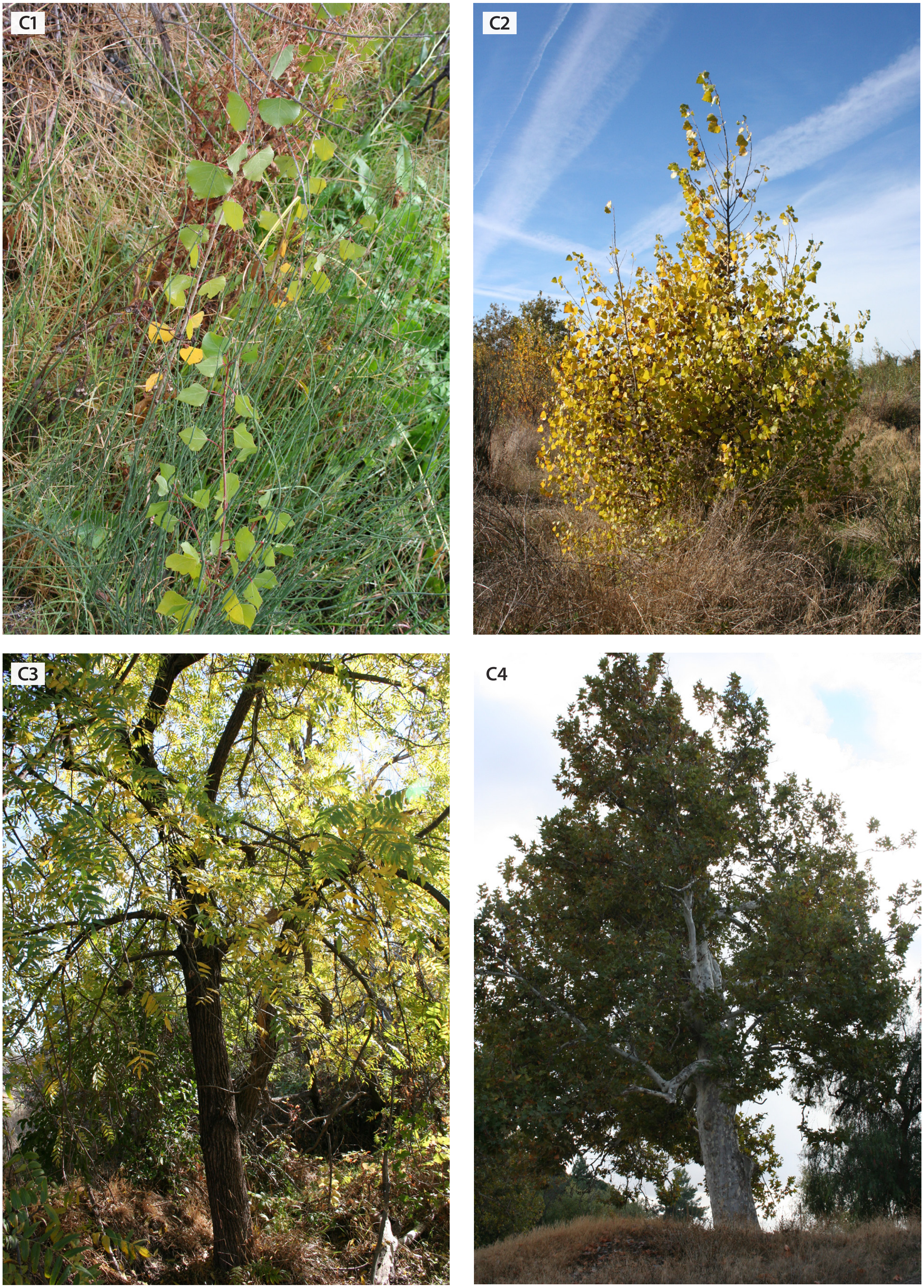


Figure B1. Representative photographs of trees in each of the four size classes used in the field surveys. C1 includes seedlings and small saplings, C2 includes medium to large size saplings, C3 includes small to medium-sized trees, and C4 includes mature trees. (photos by Sean Baumgarten and Julie Beagle, November 2012)

RESULTS

Results from the field surveys are shown in Table B1.

Total Tree Density

Overall tree density was highest in the Stanley reach (302.94 trees/acre), followed by the Holmes reach (78.81 trees/acre) and the Robertson Park reach (54.4 trees/acre) (Table B1 and Figure B2). Densities ranged from 203.32 to 485.79 trees/acre in the Stanley reach, from 8.8 to 400.55 trees/acre in the Holmes reach, and from 4.54 to 256.79 trees/acre in the Robertson Park reach.

In terms of geomorphic zone, tree density was highest in the channel (248.88 trees/acre), followed by the inner bench (78.69 trees/acre), the floodplain (22.15 trees/acre), and the outer bench (21.04 trees/acre). Tree densities ranged from 66.22 to 485.79 trees/acre in the channel, 41.06 to 212.23 trees/acre in the inner bench, 8.8 to 34.05 trees/acre in the floodplain, and 4.54 to 120.15 trees/acre in the outer bench.

Total sycamore density was highest in the Holmes reach (3.93 trees/acre), followed by the Robertson reach (1.79 trees/acre) and the Stanley reach (1.22 trees/acre). In terms of geomorphic zone, sycamore density was highest in the outer bench (3.34 trees/acre), followed by the inner bench (3.06 trees/acre), the floodplain (1.42 trees/acre), and the channel (1.28 trees/acre).

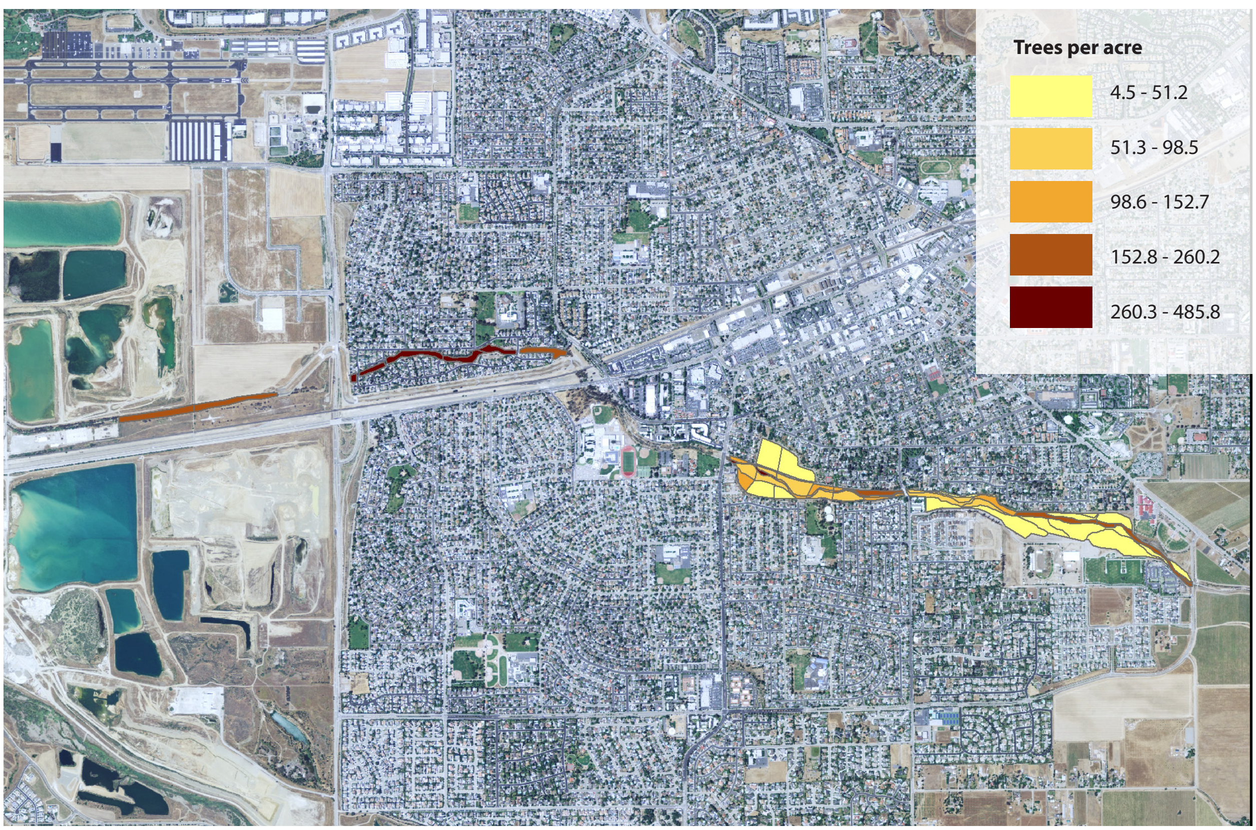


Figure B2. Total tree density in the field survey area.

Table B1. Riparian vegetation survey results. The four geomorphic zones are channel (Ch), inner bench (IB), outer bench (OB), and floodplain (FP). C1-C4 correspond to the four size classes (see Figure B1). Total Density includes all surveyed tree species; Total Density Excluding "Other" includes all willow species, cottonwood, walnut, sycamore, valley oak, live oak, tanbark oak, buckeye, and eucalyptus.

Reach	Polygon	Geomorphic Zone	Area (acres)	C1 Density	C2 Density	C3 Density	C4 Density	Total Density	"Total Density Excluding ""Other"""	"C4 Sycamore Density"	"C1 + C2 Sycamore Density"	"Total Sycamore Density"	"Total Willow Density"	"C1 Willow Density"	"C4 Willow Density"
Holmes	44	FP	4.66	1.72	4.93	2.15	0.00	8.80	0.64	0.00	0.00	0.00	0.00	0.00	0.00
Holmes	43	FP	5.23	14.35	13.20	6.31	0.19	34.05	8.23	0.00	0.96	2.68	0.00	0.00	0.00
Holmes	39	OB	3.01	4.99	25.62	5.99	0.00	36.60	24.96	0.00	4.66	7.32	6.32	0.00	0.00
Holmes	38	OB	1.53	5.22	25.47	1.31	1.31	33.31	26.78	0.00	0.00	0.00	20.90	0.00	1.31
Holmes	40	OB	1.61	25.39	74.94	16.10	3.72	120.15	42.11	3.72	2.48	11.15	8.05	0.00	0.00
Holmes	36	IB	1.65	23.03	35.15	5.46	0.00	63.64	60.01	0.00	15.15	15.15	27.88	8.49	0.00
Holmes	42	OB	0.69	11.57	57.87	7.23	0.00	76.68	62.21	0.00	8.68	10.13	26.04	0.00	0.00
Holmes	41	IB	3.11	28.60	24.42	13.49	3.86	70.36	65.86	0.00	0.32	2.89	25.70	11.89	1.61
Holmes	31	IB	1.95	13.82	49.66	15.87	8.19	87.55	69.12	0.00	0.00	0.00	20.48	5.63	0.00
Holmes	34	IB	1.22	16.36	53.99	10.63	1.64	82.62	75.26	0.00	0.00	0.00	15.54	0.82	1.64
Holmes	37	IB	1.61	16.11	68.14	13.63	0.62	98.50	97.88	0.00	0.62	6.81	26.02	2.48	0.62
Holmes	30	IB	0.30	26.67	56.67	26.67	6.67	116.68	106.68	0.00	0.00	0.00	56.67	3.33	0.00
Holmes	45	Ch	0.57	45.57	50.83	12.27	0.00	108.67	106.92	0.00	1.75	8.76	71.86	29.80	0.00
Holmes	29A	Ch	0.45	15.72	60.62	38.17	4.49	118.99	110.01	0.00	0.00	0.00	65.11	8.98	4.49
Holmes	31A	IB	0.72	24.99	69.41	51.36	6.94	152.70	118.00	2.78	0.00	6.94	62.47	4.16	2.78
Holmes	33	IB	1.01	49.29	55.20	19.72	6.90	131.11	119.28	3.94	0.00	4.93	44.36	6.90	0.00
Holmes	35	Ch	0.65	98.61	30.82	0.00	0.00	129.43	126.35	0.00	0.00	0.00	92.45	66.25	0.00
Holmes	32	Ch	0.40	83.01	45.28	0.00	0.00	128.29	128.29	0.00	0.00	0.00	85.53	42.76	0.00
Holmes	28	IB	1.70	34.68	78.77	50.56	11.76	175.77	154.02	0.59	2.35	5.88	52.91	10.58	2.94
Holmes	29	Ch	0.41	134.25	58.58	12.20	2.44	207.48	197.71	0.00	0.00	0.00	175.74	124.49	2.44
Holmes	46	Ch	0.83	340.23	60.32	0.00	0.00	400.55	396.93	0.00	0.00	0.00	283.52	235.26	0.00
Robertson Park	21	OB	2.86	1.05	0.70	2.79	0.00	4.54	4.54	0.00	0.00	2.44	2.09	1.05	0.00
Robertson Park	27	OB	7.71	1.04	3.50	0.00	0.39	4.93	4.93	0.00	0.00	0.00	0.13	0.00	0.00
Robertson Park	20	OB	3.14	5.10	0.64	0.32	0.00	6.05	5.41	0.00	0.00	0.00	0.00	0.00	0.00
Robertson Park	25	OB	5.94	0.17	1.68	6.40	1.85	10.10	10.10	0.84	1.01	4.21	0.84	0.00	0.34
Robertson Park	25A	OB	2.47	12.53	5.66	7.68	0.00	25.86	25.46	0.00	1.21	2.02	2.02	0.00	0.00
Robertson Park	20A	OB	1.30	4.61	9.99	7.69	4.61	26.91	26.14	4.61	0.77	13.07	0.77	0.00	0.00
Robertson Park	19A	IB	6.14	7.17	28.68	4.40	0.81	41.06	41.06	0.00	0.00	0.16	22.65	6.36	0.65
Robertson Park	19	IB	0.97	3.09	29.88	8.24	1.03	42.25	41.22	0.00	0.00	0.00	27.82	3.09	0.00
Robertson Park	18	IB	1.04	4.80	24.94	14.39	0.00	44.12	43.16	0.00	0.00	0.00	27.81	3.84	0.00
Robertson Park	22	IB	1.72	14.56	28.53	2.91	5.24	51.24	51.24	0.00	0.00	0.00	39.59	11.64	2.91
Robertson Park	26	Ch	2.22	18.47	45.50	1.80	0.45	66.22	66.22	0.00	2.70	3.15	48.20	15.77	0.45
Robertson Park	24	IB	1.63	20.28	47.92	6.76	2.46	77.42	76.19	0.61	1.84	4.92	17.20	4.92	1.84
Robertson Park	20B	IB	1.38	35.62	41.44	14.54	2.91	94.51	89.43	0.73	2.91	5.09	43.62	21.81	0.73
Robertson Park	23A	Ch	1.76	31.19	58.98	18.71	1.13	110.01	107.75	0.00	0.00	0.57	90.73	31.19	1.13
Robertson Park	17	IB	0.33	21.53	123.03	49.21	18.45	212.23	178.39	0.00	0.00	0.00	144.56	12.30	15.38
Robertson Park	16	Ch	0.56	51.73	128.44	12.49	1.78	194.44	194.44	0.00	1.78	1.78	169.46	37.46	0.00
Robertson Park	16A	Ch	1.47	84.43	119.83	10.21	0.68	215.16	213.79	0.00	1.36	1.36	192.69	78.30	0.68
Robertson Park	23	Ch	2.59	165.87	58.25	5.79	0.77	230.68	230.29	0.00	0.39	0.39	202.52	155.46	0.39
Robertson Park	16B	Ch	0.57	167.70	89.09	0.00	0.00	256.78	256.78	0.00	0.00	0.00	214.86	157.21	0.00
Stanley	47	Ch	2.19	52.46	99.44	71.16	15.96	239.02	180.63	0.00	6.39	8.21	15.05	8.21	0.00
Stanley	49	Ch	2.51	159.49	116.93	31.02	16.70	324.15	184.55	0.00	0.00	0.00	24.26	7.16	0.40
Stanley	52	Ch	3.56	24.71	100.82	64.31	13.48	203.32	202.76	0.00	0.00	0.00	9.27	4.49	0.00
Stanley	53	Ch	4.03	53.12	122.63	75.71	8.69	260.16	259.42	0.00	0.25	0.25	56.60	19.61	0.99
Stanley	51	Ch	0.38	76.74	148.19	95.26	7.94	328.13	296.37	0.00	0.00	0.00	7.94	5.29	0.00
Stanley	50	Ch	1.03	197.41	222.57	50.32	15.48	485.79	299.02	0.00	0.00	0.00	19.35	0.00	4.84
Stanley	48	Ch	1.57	143.67	120.79	78.19	19.71	362.36	305.78	0.00	0.00	0.00	3.18	1.91	0.00
Stanley	48A	Ch	1.87	186.67	176.01	94.94	17.07	474.68	408.01	0.00	0.53	1.07	0.53	0.53	0.00

Size Class Density

Figure B3 shows the density of each tree size class by geomorphic zone. The channel had the highest tree density for every size class, while the floodplain and outer bench had the lowest densities for each size class. However, when willows, eucalyptus, and "other" were removed from the analysis, the inner bench had the highest density of C2, C3, and C4 trees (the channel still had the highest density of C1 trees) (Figure B4).

The C2 size class had the highest density in every geomorphic zone (Figure B3). However, when willows, eucalyptus, and "other" were removed from the analysis, C1 trees were the most abundant size class within channels and on the floodplains (C2 was still the most abundant size class in the inner and outer benches) (Figure B4). Likewise, when Robertson Park and Holmes reaches were analyzed separately (i.e., the Stanley reach was excluded from the analysis), C1 trees were the most abundant size class within channels (Figures B5 and B6).

Figure B3. Total tree density by size class within each geomorphic zone in the field survey area.

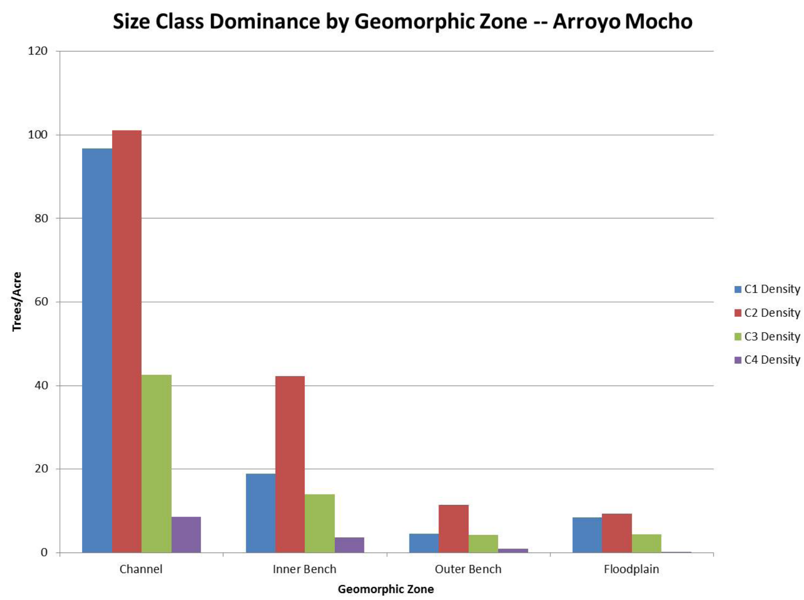
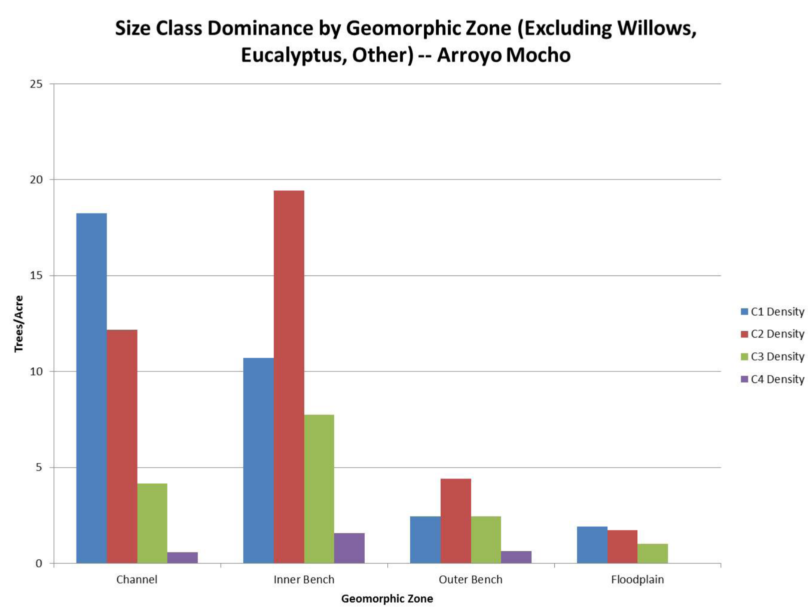


Figure B4. Tree density by size class (excluding willows, eucalyptus, other) within each geomorphic zone in the field survey area.



C4 sycamore density was highest in the Holmes reach (0.39 trees/acre), followed by the Robertson Park reach (0.28 trees/acre) (Figure B7). No C4 sycamores were observed in the Stanley reach. Combined C1 and C2 sycamore density was also highest in the Holmes reach (1.83 trees/acre), followed by the Stanley reach (0.93 trees/acre) and the Robertson Park reach (0.59 trees/acre) (Figure B8).

C1 sycamore density was highest in the inner bench (0.76 trees/acre), followed by the channel (0.44 trees/acre) and the outer bench (0.36 trees/acre) (Figure B9). C2, C3, and C4 density were highest in the outer bench (0.76, 1.65, and 0.56 trees/acre, respectively), followed by the inner bench (0.68, 1.28, and 0.34 trees/acre, respectively). No C4 sycamores were found in the channel or the floodplain.

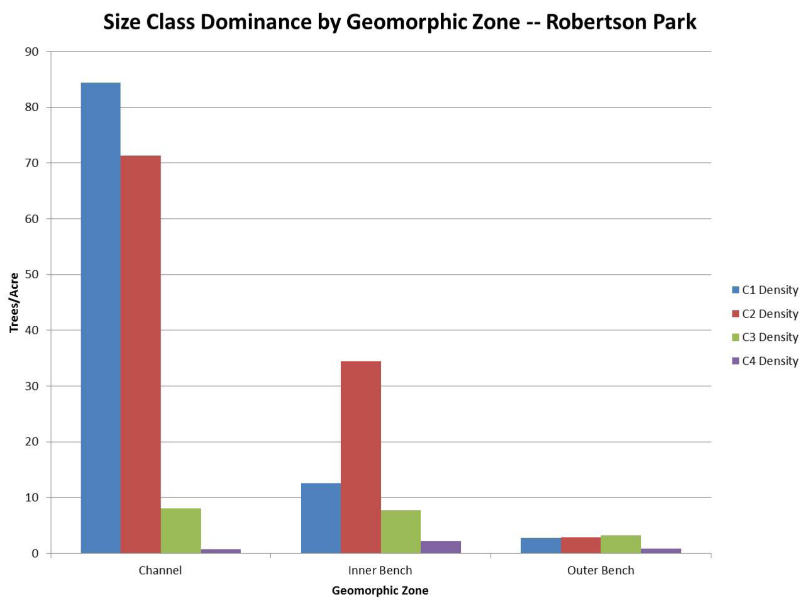


Figure B5. Total tree density by size class within each geomorphic zone in the Robertson Park reach.

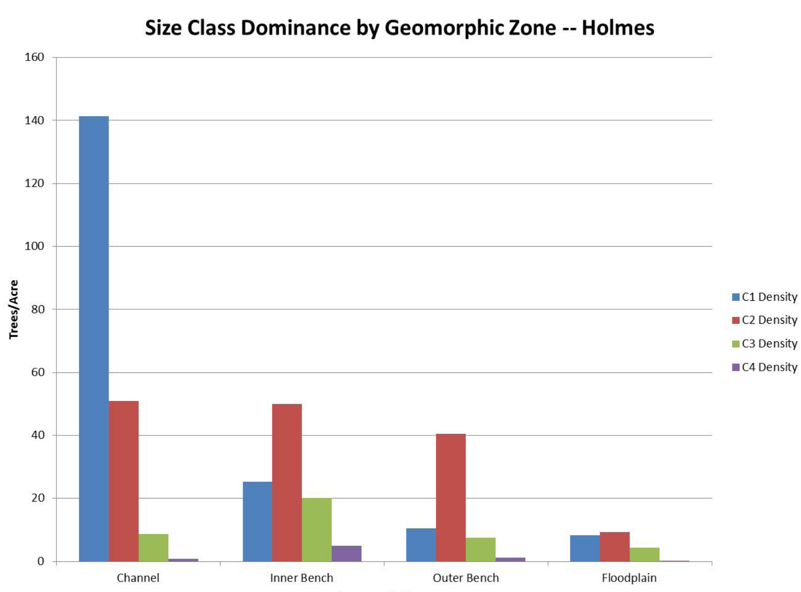


Figure B6. Total tree density by size class within each geomorphic zone in the Holmes reach.

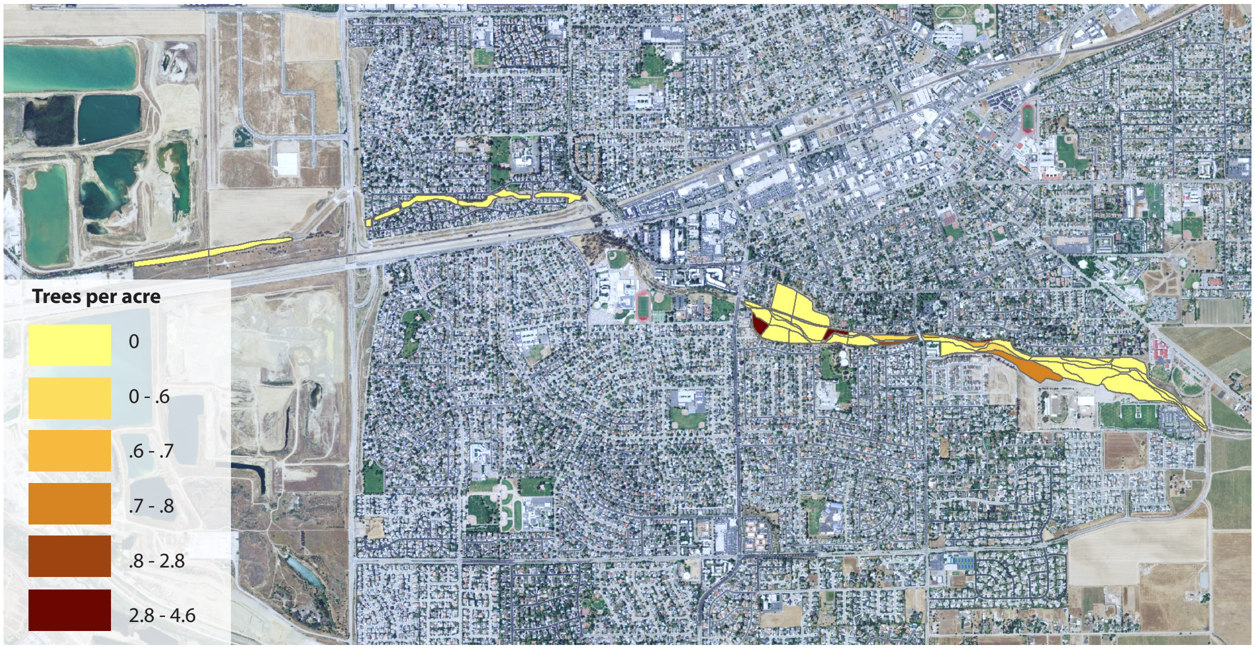


Figure B7. Density of C4 sycamores within the field survey area.

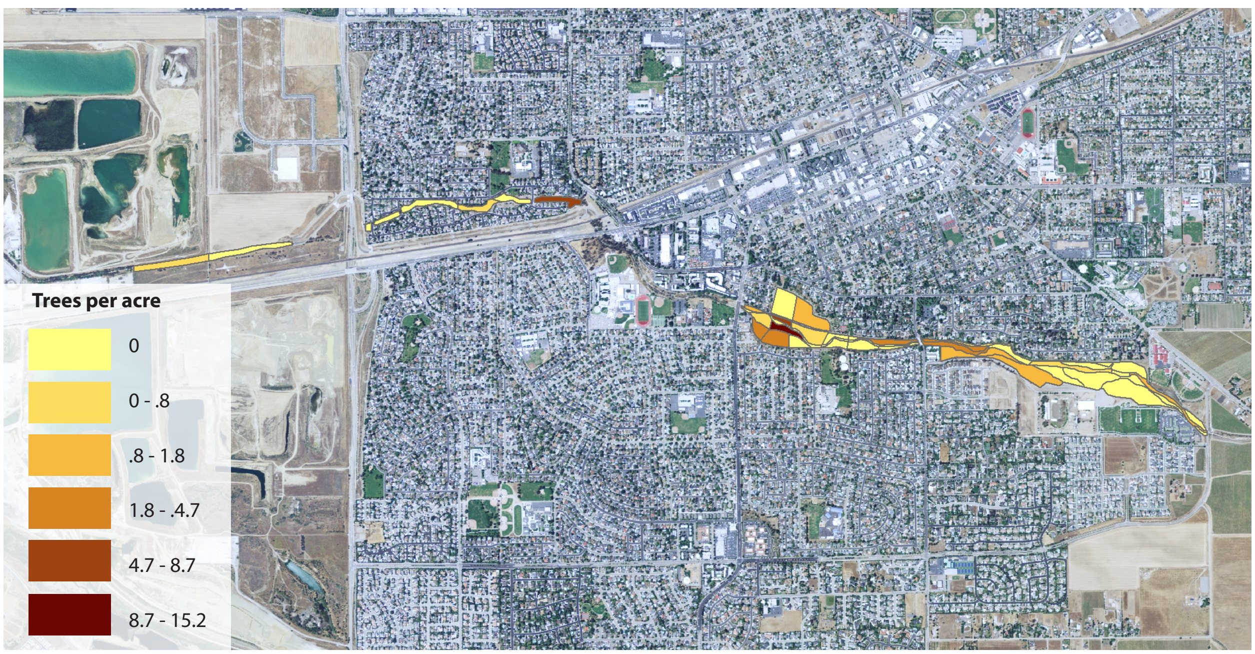


Figure B8. Density of C1 and C2 sycamores within the field survey area.

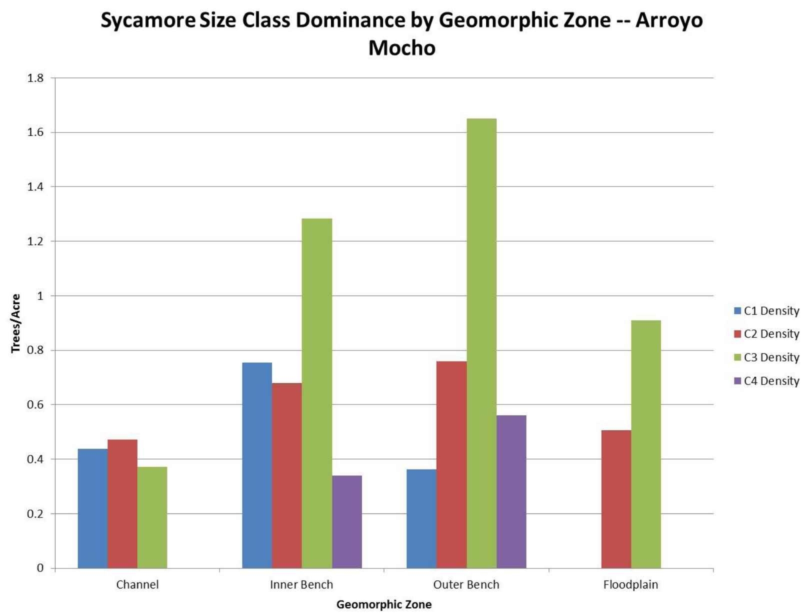


Figure B9. Density of sycamores by size class within each geomorphic zone in the field survey area.

Species Dominance

Species dominance was substantially different in the Stanley reach compared with the Robertson Park and Holmes reaches. Eucalyptus was the overwhelmingly dominant species within the Stanley reach (especially west of Isabel Avenue), which made it by far the most dominant tree species within the channel overall (Figures B10 and B11). In addition to eucalyptus, the Stanley reach also had significant numbers of other non-native species as well as live oak and sandbar willow. Native species abundance and diversity was greater in the portion of the Stanley reach east of Isabel Avenue.

In the Robertson Park and Holmes reaches, sandbar willow was the most common species in the channel (Figures B12 and B13). Within the channel there was also a relatively high density of other willow species (Robertson Park and Holmes reaches) and Fremont cottonwood (Holmes reach). Willow and walnut were common species on the inner bench in both the Robertson Park and Holmes reaches; sandbar willow was also common in the Holmes reach. "Other" was the most common category on the outer bench and floodplain in the Holmes reach (the outer bench and floodplain had a relatively high proportion of non-native ornamental trees, which were recorded in the "other" category).

Figure B10. Tree density by species within each geomorphic zone in the field survey area.

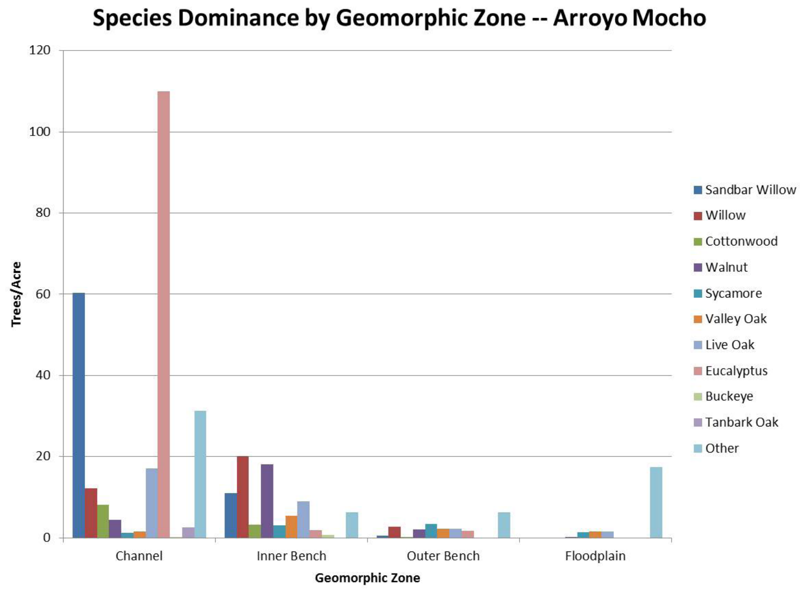
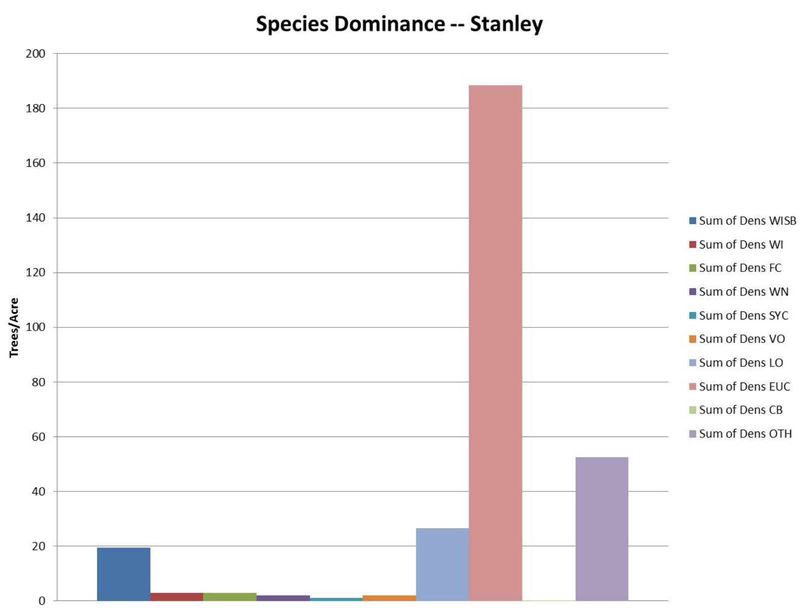


Figure B11. Tree density by species within the Stanley reach (note: "Channel" was the only geomorphic zone in the Stanley reach).



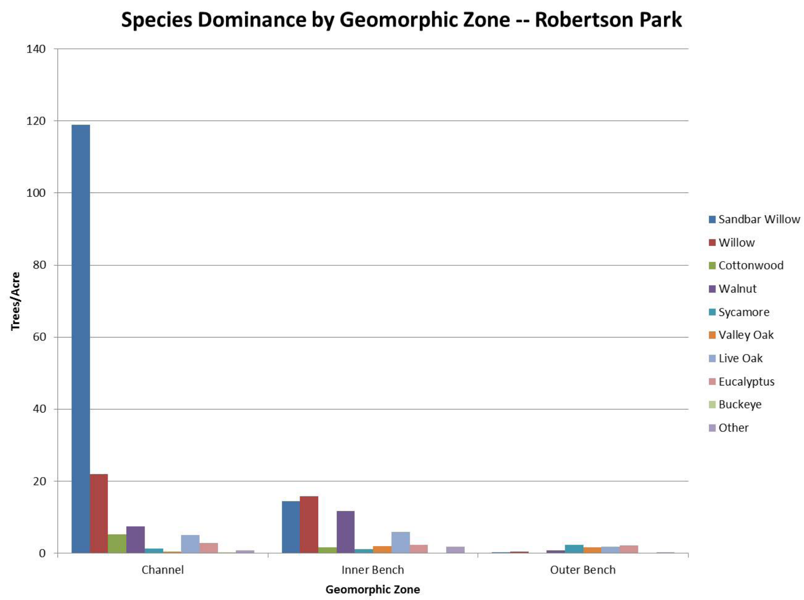


Figure B12. Tree density by species within each geomorphic zone in the Roberston Park reach.

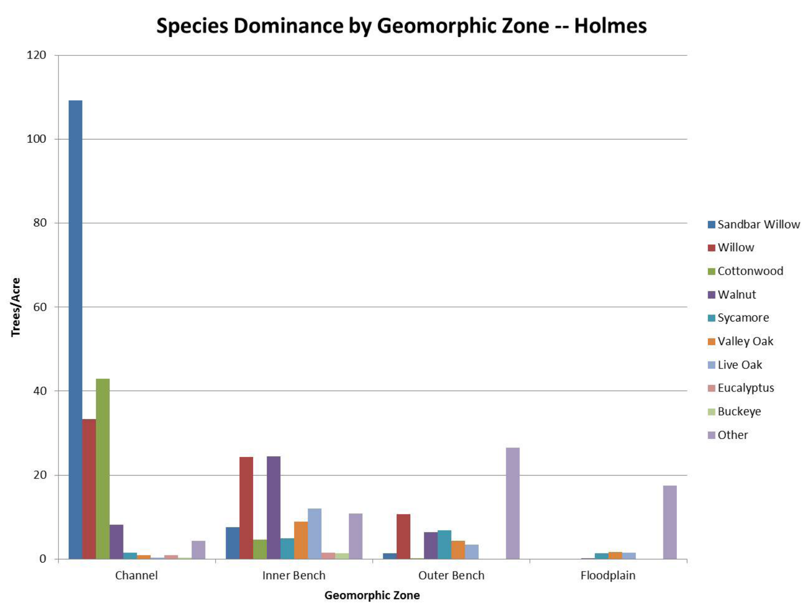


Figure B13. Tree density by species within each geomorphic zone in the Holmes reach.

DISCUSSION

The current condition of riparian vegetation within the Arroyo Mocho case study areas varies considerably by reach as well as by geomorphic zone. The Robertson Park and Holmes reaches support a moderate density mixed riparian forest comprised of native species such as willow, cottonwood, walnut, valley oak, and sycamore, as well as smaller numbers of non-native trees such as plum, pepper, and olive. Riparian vegetation in the Stanley reach is substantially denser. The portion of the Stanley reach east of Isabel Avenue is composed of a dense mixture of native and non-native tree species, while the flood control channel to the west of Isabel Avenue is dominated by dense stands of eucalyptus.

In all three reaches, riparian vegetation is likely much denser than it was historically, and is composed of different plant associations. The change is most apparent in the Stanley reach, where the very high density vegetation that exists today is in marked contrast to the sparse oaks and grasses that dominated the riparian corridor in this reach historically (the historical channel was also in a slightly different location than the modern channel). Riparian vegetation in the Robertson Park and Holmes reaches historically consisted of somewhat denser sycamore alluvial woodland, but this was still less dense than the mixed riparian forest that occurs in these reaches today. Augmented streamflows resulting from urban runoff and the addition of SWP water upstream are likely responsible for much of the vegetation encroachment within the stream corridor. Vegetation encroachment causes the channel to become more confined and stabilized, and thus restoration of a braided channel may require active intervention to reduce vegetation density.

Relatively high densities of mature (C3 and C4) sycamores were observed on the inner and outer benches of the Robertson Park and Holmes reaches (see Figures B7 and B9). Historically, these were braided reaches with intermittent flows that supported sycamore alluvial woodland, and were in turn stabilized by the presence of sycamores. The remnant mature sycamores in these reaches probably established following a flood event when these areas were still part of the active floodplain. Many of these sycamores are "perched" on mounds of dirt above the floodplain, which have become isolated as sediment deposition on these benches has decreased.

As evidenced by the presence of C1 trees, sycamores are regenerating to some degree in all three reaches that we surveyed. The majority of C1 sycamores that we observed were in the Holmes reach. Sycamore recruitment rates appear to be relatively low, however, and given the lack of recent flood events in areas where sycamores are regenerating, the new recruits are likely the result of vegetative reproduction.