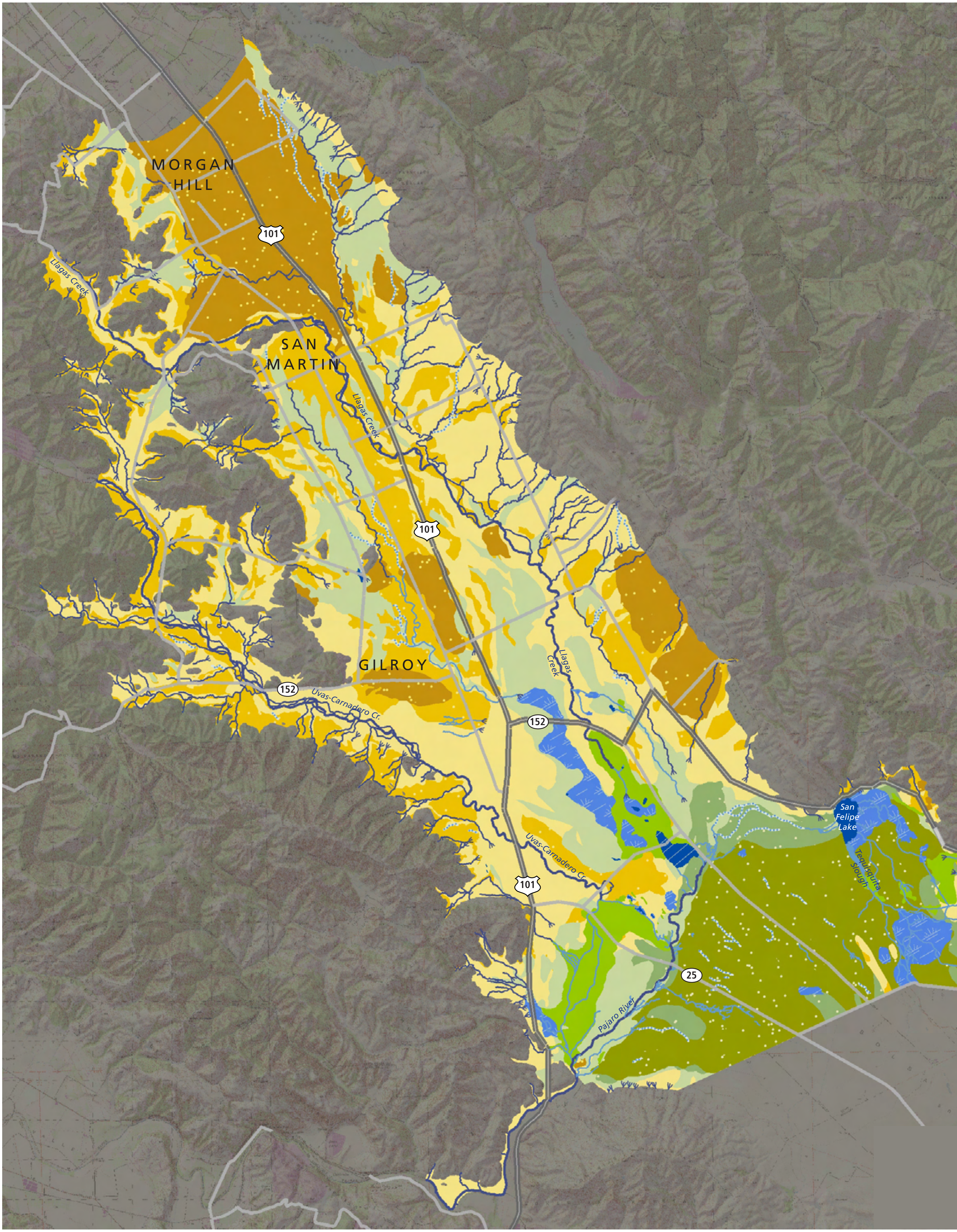
FINAL REPORT

SOUTH SANTA CLARA VALLEY HISTORICAL ECOLOGY STUDY

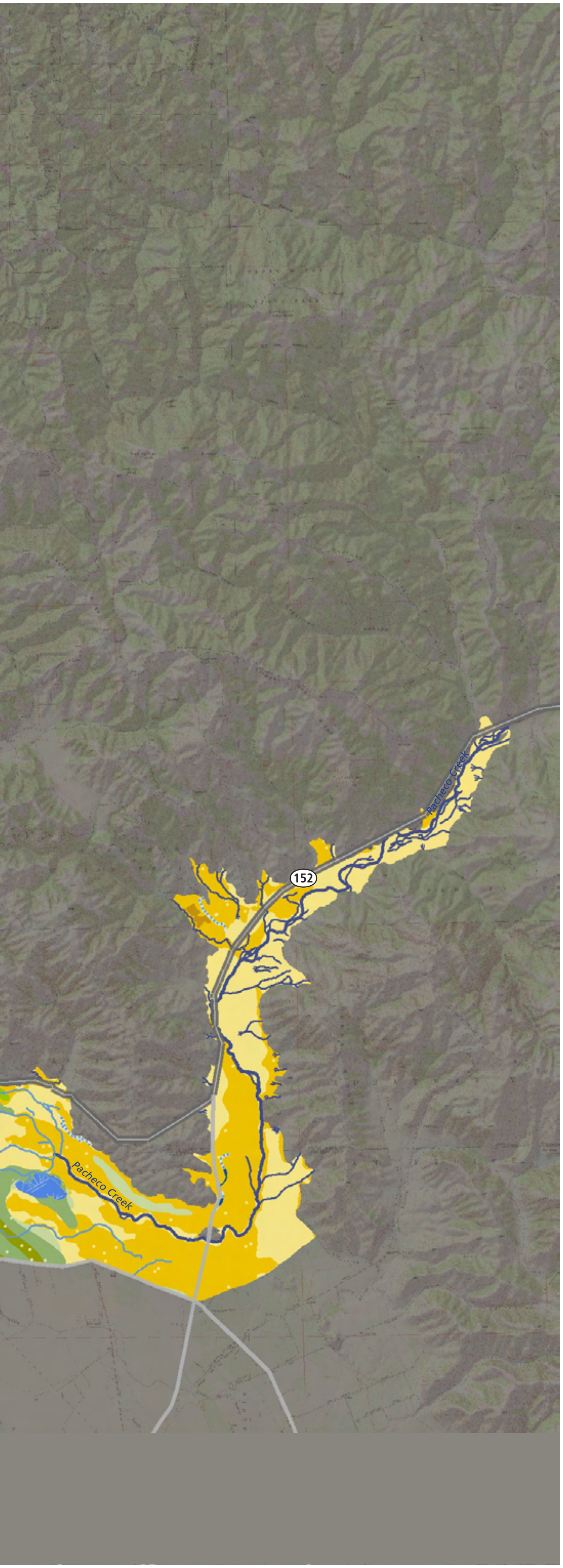
INCLUDING SOAP LAKE, THE UPPER PAJARO RIVER, AND LLAGAS, UVAS-CARNADERO, AND PACHECO CREEKS

SAN FRANCISCO ESTUARY INSTITUTE

PREPARED FOR THE SANTA CLARA VALLEY WATER DISTRICT
AND THE NATURE CONSERVANCY
MAY 2008



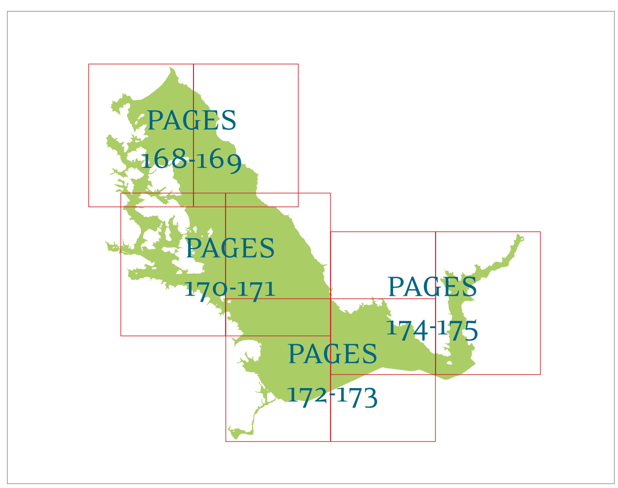
MORGAN HILL
101
Llagas Creek
SAN MARTIN
Llagas Creek
101
GILROY
Llagas Creek
152
Uvas-Carnadero Cr.
152
San Felipe Lake
Tequisquita Slough
Uvas-Carnadero Cr.
101
25
Pajaro River

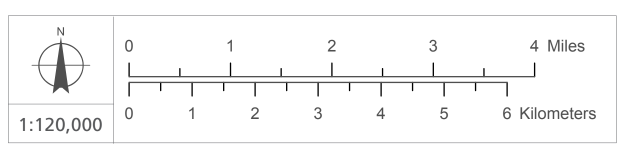


HISTORICAL CONDITIONS, CIRCA 1800

- Perennial Freshwater Pond
- Seasonal Lake/Pond
- Valley Freshwater Marsh
- Alkali Meadow (low concentration)
- Alkali Meadow (high concentration)
- Wet Meadow
- Willow Grove
- Oak Woodland
- Oak Savanna
- Grassland
- Mainstem Stream
- Tributary Creek or Side Channel
- Floodplain Slough
- Swale

The map at left reconstructs the habitat characteristics of south Santa Clara Valley prior to significant Euro-American modification. More detailed views are provided on pages 168 through 175, in the map sections shown below.





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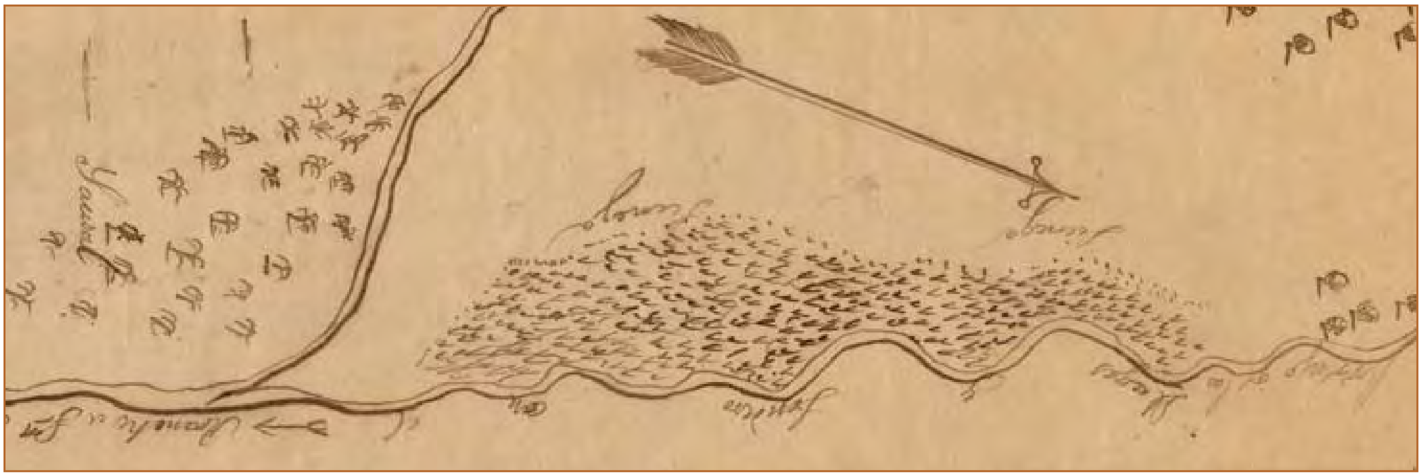

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Front cover: Irrigation canal on Emery Ranch, Soap Lake, looking downstream, ca. 1900.
Courtesy of the San Benito County Historical Society

Title page: Diseño showing Llagas and Carnadero creeks.
Courtesy of The Bancroft Library, UC Berkeley

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EXECUTIVE SUMMARY

OVERVIEW

This report synthesizes an array of historical records to document historical conditions, landscape trends, and restoration opportunities in the southern part of the Santa Clara Valley. It has been developed at the request of the Santa Clara Valley Water District (SCVWD) and The Nature Conservancy (TNC) to inform strategies for natural flood protection, habitat conservation and restoration, and other environmental management challenges.

To develop the historical data set for this study, we reviewed thousands of historical records at local and regional archives. Several hundred of these contributed useful information to the study. Historical records were compiled into a geo-database and synthesized into a composite map describing landscape conditions prior to significant Euro-American modification. Data collection and analysis focused on the south Santa Clara Valley, from Morgan Hill south to Shore Road. This area includes the heavily modified alluvial channels, fans, and floodplains of Uvas-Carnadero, Llagas, and Pacheco creeks, the upper Pajaro River, and most of the Soap Lake floodplain. Approximately 80% of the study area is located in Santa Clara County; the southern portion of the study area extends across the Pajaro River (the county line) into San Benito County to include its floodplain. This area includes San Felipe Lake and its surrounding lowlands, often called the Bolsa.

The historical record for south Santa Clara Valley ("South Valley") represents a robust resource for understanding how contemporary conditions have evolved and identifying the potential strategies for environmental recovery. The map of historical habitats shows how the local landscape successfully supported native species in the relatively recent past and, in many cases, suggests the physical factors that control habitat formation and maintenance. In the context of information about present-day conditions and future projections, historical ecology can be used by scientists, policy makers, and local residents to design locally appropriate plans that are supported by persistent landscape processes.

FINDINGS

LANDSCAPE LEVEL

The native South Valley landscape supported a diverse array of habitats, from dense valley oak woodlands in the north to repeating wetland mosaics in the southern part of the study area. The valley was almost evenly divided between grassland, oak savanna/woodland, and wetlands (including seasonal and perennial wetlands).

Historical habitat distribution was heterogeneous and can be largely explained by identifiable physical characteristics. Factors such as topography, soils, and hydrology are still likely to affect restoration potential. Consideration of historical habitat controls should improve the likelihood of restoration success.

Some of the native habitats and species that have experienced greatest local decline – such as sycamore alluvial woodland, lesser nighthawk, and least Bell's vireo – are at the northern margin of their historical range. Given anticipated climate changes and associated shifts in species range, these may be of greater local conservation importance in the future.

STREAMS AND RIPARIAN HABITATS

Prior to Euro-American settlement, the South Valley drainage network was much more discontinuous and diffuse. Streams commonly did not maintain defined channels across the entire valley floor. Instead, they sank into their alluvial fans and recharged groundwater, or spread into wetlands. Many channels were relatively shallow and prone to flooding. Sloughs and swales were common.

The drainage network has been expanded to drain the valley floor. Over 40% of the contemporary channel network was artificially constructed using new alignments.

Most of the valley floor stream reaches were historically intermittent. Extensive historical evidence confirms that long reaches of Uvas-Carnadero, Llagas, and Pacheco creeks were seasonally dry across the valley floor.

Some intermittent reaches had persistent pools fed by subsurface flow. Pools were valued as fishing and swimming holes from native times through the early 20th century.

There were limited perennial stream reaches on the valley floor. Perennial flow on major creeks appears to have extended some distance downstream from the canyon mouth and, in some cases, reappeared where the lower reaches of streams intercepted groundwater.

The Pajaro River had unique ecological and hydrogeomorphic characteristics. Located in the historical artesian zone, the upper Pajaro River (San Benito River to Llagas Creek) had perennial flow and a dense, mixed riparian forest canopy, in contrast to other major South Valley streams.

Braided stream morphology was common on the major South Valley creeks. These broad reaches were interspersed with narrower, single thread reaches. Corresponding riparian habitat patterns were observed.

Open riparian savannas and woodlands dominated by California sycamore characterized the braided stream channels of South Valley. These high energy habitats included riparian scrub, occasional other riparian trees, and broad, unvegetated gravel beds and bars. Sycamore patterns varied from occasional, widely spaced trees along narrower channels to larger woodland groves on broad bars and terraces.

Riparian forest typically extended downstream from the canyon mouth on major South Valley creeks. The spatial transition from riparian forest to open riparian canopy was quite abrupt.

As a result of reservoir construction and operation, there has been a general conversion of open riparian canopy habitat to more densely wooded environments. The total length of forested reaches on the valley floor has more than doubled, while savanna and woodland reaches have decreased substantially.

Stream corridors have also consistently been constricted by land use changes. While riparian corridors wider than 60m (200 ft) were historically prevalent on the Uvas-Carnadero, Llagas, Pacheco, and Pajaro (70% of their valley floor length), now 70% of their length is narrower than 60 m (200 ft).

The lower reaches of Uvas-Carnadero, Llagas, and Pacheco creeks had substantial wetland reaches, where they spread into broad mosaics of willow groves and freshwater marsh. These areas provided an array of functions, including flood peak attenuation, fine sediment storage, and habitat for a diverse array of plants and wildlife, including a number of special status species.

While sycamore riparian habitat has been altered on most stream reaches, a significant remnant still exists on Pacheco Creek. This habitat is a regionally significant example of Central Coast Sycamore Alluvial Woodland.

Management considerations

Stream restoration could potentially reestablish natural stream benches and associated sycamore riparian habitat as part of natural flood protection efforts. For example, large remnant sycamore trees still remain along Llagas Creek, and could potentially be reconnected to the channel through restoration. Without specific efforts, this major element of the local natural heritage will probably disappear. Stream benches with scattered sycamores could also be re-created.

The Pacheco Creek sycamore alluvial woodland should be considered for its conservation value. Further research is needed to evaluate whether its long term health that would be improved through the use of scouring flood flows, carefully timed moistening flows for seedling recruitment, grazing management, and/or other stewardship actions.

Natural flow regimes have been altered on streams with large reservoirs. There may be further opportunities to adjust the timing and size of managed releases for ecological and geomorphic benefits. Higher flow pulse releases could potentially benefit natural stream maintenance processes, sycamore regeneration, and native fish populations. Well-timed late spring/early summer releases could potentially benefit both steelhead smolt outmigration and sycamore seedling establishment.

Different aquatic and riparian conditions may be appropriate targets for different stream reaches. Stream reaches can be evaluated in the context of the overall upper Pajaro River watershed by scientists, engineers, and water managers for appropriate, achievable reach-specific targets. Otherwise, stream habitat objectives may be in conflict. For example, summer water releases intended to benefit steelhead may have negative effects on remaining sycamore woodlands. Comparing historical conditions and existing potential may help identify viable strategies to balance competing resource objectives.

WETLAND HABITATS

Prior to Euro-American drainage efforts, wetlands occupied about 9,000 ha (22,000 ac) in South Valley. Most of these (83%) were seasonal wetlands, including wet meadows and alkali meadows. There were also 700 to 800 ha (1,700-2,000 ac) of perennial valley freshwater marsh and of willow groves.

Wetlands occurred in distinct landscape positions. Perennial freshwater ponds and marshes were always associated with fine-grained, clay-rich soils. Willow groves consistently occupied the margin between these poorly drained soils and adjacent coarser materials. Willow groves also followed groundwater discharge, associated with the outer margin of artesian conditions. Similar positions can be identified today.

Wetlands have experienced dramatic changes in total extent and other spatial characteristics. When compared with contemporary maps, historical sources indicate that the area of valley freshwater marsh has decreased by 90%. Willow riparian forest has decreased by a lesser amount (~60%), but the edge-to-area ratio of the remaining, more linear habitat patches has increased by over 700% compared to the historical habitats.

Alkali meadows dominated the Bolsa. These now rare habitats were extensive along the southern side of the Santa Clara-San Benito County line. Perennial marshes – both freshwater and saline – and ponds were scattered throughout the alkali meadows. Except for willow groves on the margins, trees were rare or absent.

Most of the wetlands in the study area were associated with the Soap Lake floodplain, a broad natural basin that historically supported a diverse and extensive array of wetlands. Topographic position, poorly drained soils, persistent alkaline soil effects, and seasonal flooding continue to give the area relatively high potential for wetland restoration.

Some significant wetland remnants remain. San Felipe Lake retains some of its historical size and function (see below). Several of the smaller historical willow groves are still intact.

Small portions of historical wetlands have recently reestablished as groundwater levels have recovered and some areas have become less intensively managed. In particular, small willow groves and scattered individual willow trees can be seen within the extent of historical willow groves.

Mosaics of willow groves, freshwater marsh, perennial pond, and seasonal wetland provided an array of species support functions. Willow groves and freshwater marsh almost always co-occurred. Both habitats were always fully or partially bordered by seasonal wetlands. Perennial ponds were generally surrounded by freshwater marsh.

San Felipe Lake, an Audubon Important Bird Area, has decreased in size and depth, and the surrounding wetland mosaic has been reduced. This rare regional example of a natural perennial freshwater lake was a cultural and ecological centerpoint for hunting, fishing, and soap-making. While the lake retains 50-60% of its historical area, the freshwater marshlands bordering the lake have been almost completely eliminated (93%).

San Felipe Lake historically overflowed into a series of sloughs, swales, and wetlands that converged into the Pajaro River at the Llagas Creek confluence. This diffuse drainage system had no well-defined channel or riparian corridor but rather a chain of seasonal and perennial wetlands.

Management considerations

Historical wetland locations offer a number of sites that should be considered for conservation and stewardship. Significant remnants include San Felipe Lake and the nearby remnant willow groves. There is also significant potential for wetland restoration along Tequiquita Slough and lower Pacheco, Llagas, and Ulvas-Carnadero creeks.

The potential to restore wetland mosaics in the Soap Lake floodplain is regionally significant. A number of factors suggest that restoration is technically feasible. Restoration could potentially benefit numerous species, including an array of native songbirds, shorebirds and waterfowl, floodplain-associated fish, outmigrant juvenile steelhead, and amphibians.

Historical wetland mosaics present a template for wetland restoration design. Dynamic floodplain wetland mosaics – incorporating willow groves, freshwater marsh and pond, and wet/alkali meadows – are likely to be able to support multiple life history stages of numerous species within relatively small areas. Restoration strategies can recognize existing topographic, edaphic, and hydrologic gradients to reestablish these kinds of patterns.

OAK SAVANNA AND WOODLAND

Valley oak savannas and woodlands occupied much of southern Santa Clara Valley outside of the Soap Lake floodplain. These oak lands covered an estimated 9,000 ha (22,000 ac) and have declined by 98%. We estimate that there were 60,000 oak trees, of which about 1,000 remain.

Oaks occurred on the valley floor in a range of densities. Relatively open savanna with scattered trees was most common (5,700 ha/14,000 ac), corresponding to an average stand density of about three trees/ha and an estimated canopy cover of 12%. There were also much denser valley oak woodlands. We identified an estimated 3,300 ha (8,000 ac) of woodland, with an average of 13 trees/ha, and an estimated canopy cover of approximately 50%.

Valley oaks dominated the oak lands of South Valley. 84% of the oaks recorded to species level by mid 19th-century General Land Office surveyors were valley oaks. Black oak and live oak were minor components overall, but there are indications that they could be more dominant in certain places.

Valley oaks declined dramatically during late 19th century conversion of woodlands to orchards. While the presence of large oak trees conflicted directly with the development of densely planted orchards, the trees have posed less direct conflict with other local land uses, including grazing, hay and grain farming, and even residential development, where they have been valued for shade and aesthetic value.

There are just a few remaining historical oak groves. These provide the last remaining local examples of the habitat.

Management considerations

While the extent of valley oak lands has declined precipitously, there are many trees and a few groves that have been preserved to date. In addition to stewardship of remaining individual trees, these significant remnant groves may be worthy of conservation attention.

The historical spatial patterns of valley oak in South Valley suggest that reintegration of oak habitat within the contemporary landscape is possible. Within the context of an urban forestry plan, valley oaks could be strategically reintroduced (in medians, parks, yards, and along road and fence lines) to achieve densities similar to historical conditions.

Increasing the density of oaks may be important to allow successful oak reproduction and maintain a healthy population. Existing trees may be genetically isolated and thus have less ability to successfully adapt to changing conditions.

Valley oak restoration could benefit a number of native species whose ranges have been declining in South Valley, such as acorn woodpecker and Pacific pallid bat. Certain oak-associated species are largely precluded from the valley by the lack of oak trees.

Valley oak restoration can have a number of practical and aesthetic benefits. As shade trees, they are recognized for being attractive, deciduous, relatively fast-growing, and drought tolerant.

ACKNOWLEDGMENTS

Like any historical research effort, this one is indebted to the expertise and assistance of staff at a number of archives. We would like to express our appreciation to Susan Snyder, Lorna Kirwan, Cynthia Rollins, and Erica Nordmeier at The Bancroft Library, UC Berkeley; Virgil Bella, Ramona Ramstead, Lonnie Spin, and Bob Teeter at the SCVWD vault and archive; Robert Rohde at the USDA-NRCS; Sheila Prader and Earlene McCabe at the San Benito County Historical Society; Tom Howard and Susan Voss at the Gilroy Museum; Bud O'Hare at the Morgan Hill Historical Society; Gwen Gee and Jack Schepens at the Santa Clara County Surveyor's Office; Lillian Perreira at the San Benito County Recorder's Office; and Arman Nazemi and Cindy Cecena at San Benito County Public Works. In addition, staff at the California Historical Society provided invaluable help and resources.

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Several local residents were extremely gracious with their time and provided us with first-hand account of local landscape change. Sig Sanchez, Jack and Dorothy Sturla, and Peter Van Dyke generously shared their knowledge and experience.

Internship programs at local universities contributed to the development of this project. Alison Whipple started on the project as an intern of Stanford University's Bill Lane Center for the Study of the North American West and led the research into oak woodlands. Bronwen Stanford, from the same program, assisted in the completion of this report. Jeanette Moritz contributed greatly to the GIS and report development as an intern of Santa Clara University's Anthropology Department. We would like to thank Julie Martinez, Internship

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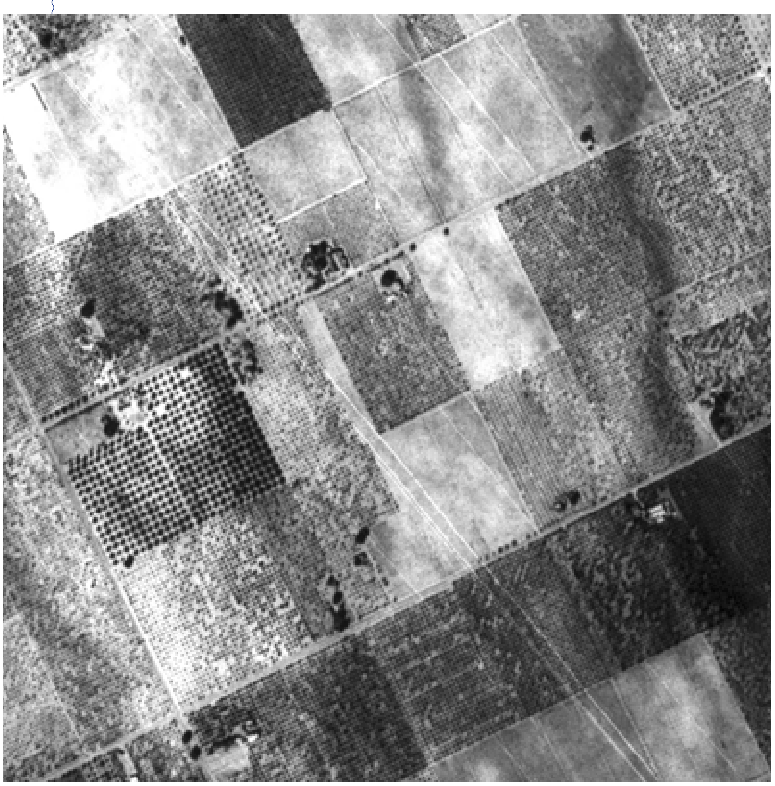
1 INTRODUCTION



Above. Llagas Creek ca. 1895. *Below.* Grid patterns of orchard plantings in 1939.

INTRODUCTION

This report synthesizes an array of historical records to document historical conditions, landscape trends, and restoration opportunities in the southern part of the Santa Clara Valley ("South Valley"). A number of local environmental planning efforts have recognized the need for a better understanding of the historical ecology of the area to inform the protection and enhancement of local natural resources. Accordingly, this historical analysis has been developed to inform strategies for restoration and conservation, natural flood protection, and other environmental management challenges.

While substantial ecological resources currently remain in South Valley, landscape change has been extensive. Little knowledge currently exists about the pre-modification distribution of habitats, the processes that controlled their formation and maintenance, and the changes that have resulted from subsequent land use patterns. The study of historical ecology can address these information gaps, providing a technical basis for successful environmental planning (NRC 1992, Montgomery 2008).

This report and the associated geo-database provide a spatially comprehensive dataset about the natural distribution, abundance, and functions of the native habitats of South Valley. This information is designed to support current planning efforts such as the conservation program of the Santa Clara Valley Water District, the Llagas Creek Flood Protection Project, the Santa Clara Valley Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP), and the Mt. Hamilton Project of The Nature Conservancy. This information is also made publicly available as an information resource to other local and regional planning efforts such as city and county general plans, city and county parks planning, and flood protection planning for the overall Pajaro River watershed.

ENVIRONMENTAL SETTING

The South Santa Clara Valley Historical Ecology Study focuses on the habitats and drainage patterns of the valley floor, where change has been greatest. We identify landscape characteristics prior to significant Euro-American modification and discuss some of the subsequent impacts and changes.

The study examines the alluvial reaches and adjacent valleys of the major streams of South Valley. The study area includes Llagas Creek, Uvas-Carnadero Creek, and Pacheco Creek, downstream of their canyon mouths; the upper Pajaro River (to which the above-mentioned creeks are tributary); and the Soap Lake/Upper Pajaro floodplain as far south as Shore Road (fig. 1.1). Our project boundary crosses the Santa Clara County border into San Benito County, since the Pajaro River and its floodplain straddle both counties. The contact between Quaternary alluvial deposits and bedrock defines the valley floor, and was used as the eastern and western study area boundary (Knudsen et al. 2000). At the northern end of the study

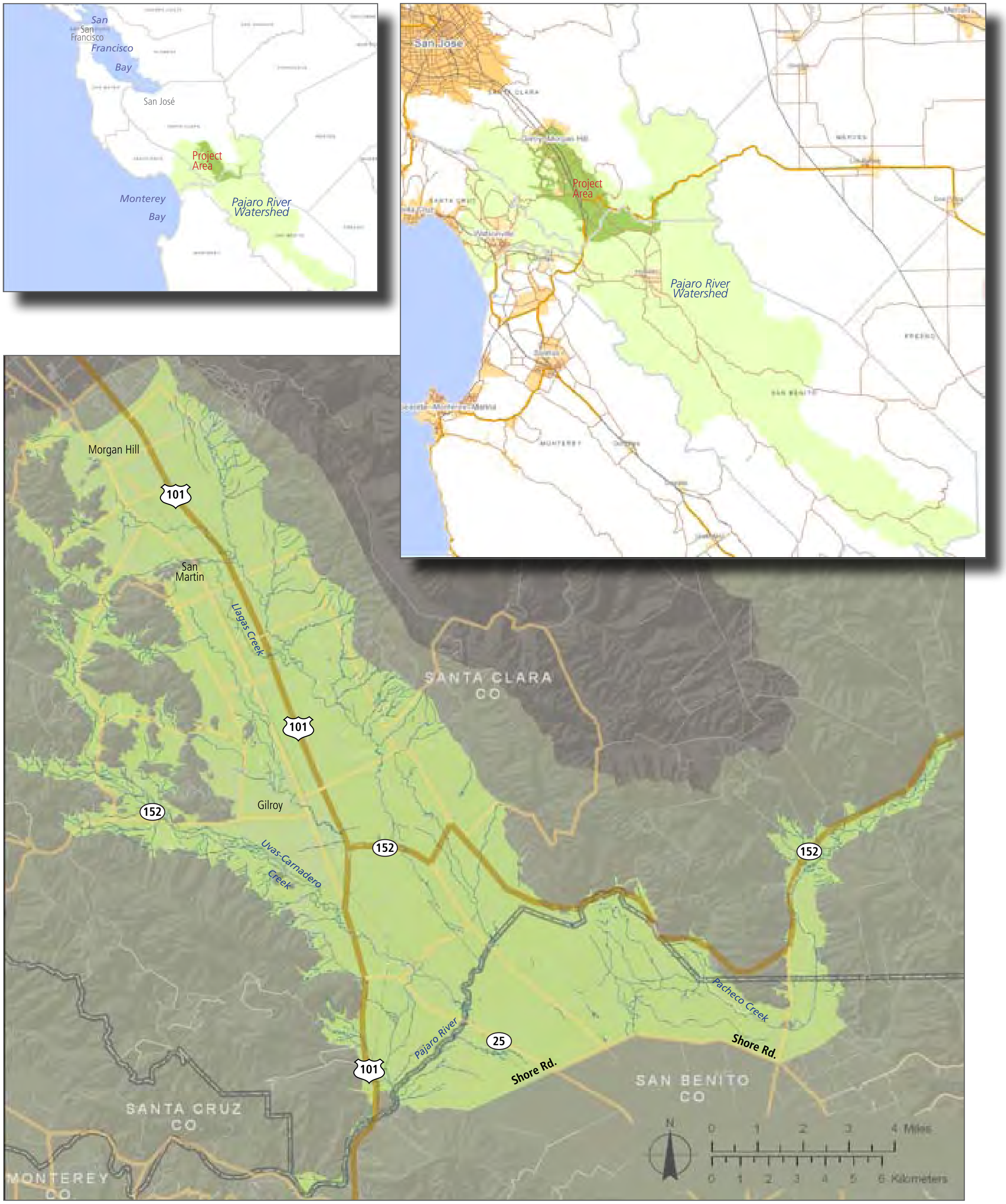


Figure 1.1. Study area and geographic locator maps.

area, the historical ecology mapping and research adjoins the Coyote Creek watershed, previously described in the Coyote Creek Historical Ecology Study (Grossinger et al. 2006). The southern boundary was defined by Shore Road. While this extent includes most of the floodplain wetland areas of the upper Pajaro River, it does exclude all but the lower reaches of several tributary creeks that enter from the south (e.g., Santa Ana, De las Víboras, and Dos Picachos).

Southern Santa Clara Valley is the very southern portion of the regional topographic depression that forms San Francisco Bay, Santa Clara Valley to the south, and Petaluma, Sonoma, and Napa valleys to the north (Norris and Webb 1990). While most of Santa Clara Valley drains north into San Francisco Bay, the streams of South Santa Clara Valley flow south to the Pajaro River and eventually into Monterey Bay. A subtle topographic inflection near the city of Morgan Hill divides these two parts of the valley. At its southern end, south Santa Clara Valley crosses the Santa Clara County line and merges into the Bolsa and Hollister Valley.

The primary population centers of South Valley are Morgan Hill and Gilroy. As the eighth and tenth largest cities in Santa Clara County respectively, these rapidly growing cities are nevertheless still smaller than the historically dominant cities to the north. Other recognized communities in the area include San Martin, Dunneville, and San Felipe. Hollister and San Juan Batista are located within 5 miles south of the study area. While most of South Valley lies in Santa Clara County, its southern end continues into neighboring San Benito County.

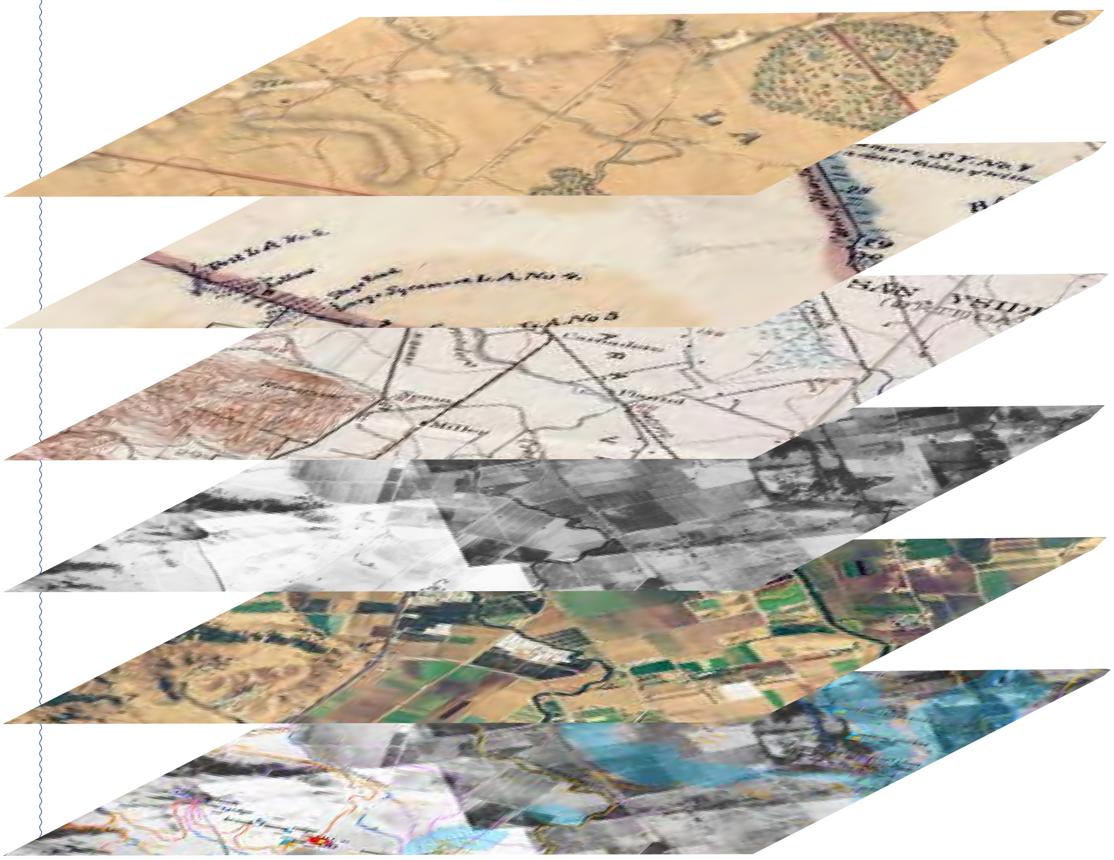
Oriented in a northwest fashion, southern Santa Clara Valley is bordered by the western front of the Diablo Range to the east and the Santa Cruz Mountains to the west. These portions of California's Coast Range are dominated by units of the Jura-Cretaceous Franciscan Complex and Great Valley Complex. The valley itself is a gently sloped alluvial plain of Late Quaternary origin, its surface shaped by patterns of floodplain deposition. The streams of South Valley converge with Pacheco Creek and drainages from the east into the Bolsa, a broad, low-lying area bridging the Santa Clara-San Benito County line. Referred to as the Bolsa (pocket) since Spanish times, the area has alternatively been called the San Felipe Sink (Milliken et al. 1993), the Pajaro Plains (Taylor 1850), the Soap Lake Floodplain (RMC 2005), or simply Soap Lake. The Calaveras Fault crosses the southern portion of the study area, contributing to the formation of San Felipe Lake. The region is characterized by a mild Mediterranean-type, semi-arid climate, with nearly all of the annual precipitation occurring from November through April, and a dry season May through October.

Population expansion and other land use change trends in South Valley have generally lagged several decades behind those of the dominant population centers to the north. Accordingly, the region still maintains a mix of urban, suburban, and agricultural land uses. The region is also shaped by the long-term presence of several major transportation corridors. The west side of the valley was well traveled during pre-colonial, colonial, and modern times as the link between the San Francisco Bay area and the Monterey Bay area, as well as areas further to the south. El Camino Real connected Monterey and San José through South Valley. Highway 101 is a major transportation corridor linking the south San Francisco Bay area and Silicon Valley to Monterey Bay and southern California. Highway 152 is also part of a major north-south corridor, but here follows a generally east-west orientation. It connects Highway 101 at Gilroy to Highway 5 in the Central Valley over Pacheco Pass, largely following Pacheco Creek. Transportation infrastructure and related development patterns may continue to affect South Valley, as the proposed route of the high-speed rail between the San Francisco Bay area and southern California crosses the Soap Lake floodplain and follows the general Highway 152-Pacheco Creek alignment.

REPORT STRUCTURE

The report is divided into eight chapters. This introductory chapter describes the project, its spatial extent, and the general environmental and geographic setting. The second chapter, General Methods, describes the basic approaches used to acquire, interpret, and synthesize information about the historical landscape. The third chapter is a Land Use History for the region. This history provides important context for interpreting historical data from these time periods. Chapters 4-6 describe specific methods and present our findings about each of the major habitat types found in the study area: Stream and Riparian Habitats, Wetland Habitats, and Oak Savannas/Woodlands. In Chapter 7, Local Landscape Descriptions, we describe the native landscape geographically, showing how the different landscape elements fit together at a regional scale, and then describe local features subregion by subregion. Finally, Chapter 8 summarizes key findings. Appendices discuss the local climate history and present information about historical fish assemblages.

2 GENERAL METHODS



Above. Maps assembled from different time periods in a geographic information system.

GENERAL METHODS

This section describes the general research methods used throughout the study. Additional description of methods specific to each habitat type is provided in the landscape analysis chapters (Chapters 4-6).

DATA COLLECTION

A substantial variety and quantity of historical records are needed for accurate assessment of the historical ecological landscape (Grossinger 2005, Grossinger et al. 2007a). With this in mind, we assembled a diverse range of historical records spanning more than a century and compiled these data into a map of landscape patterns prior to significant Euro-American impact.

Assembled materials include narrative data (e.g., Spanish explorers' accounts, Mexican land grant case court testimonies, General Land Office records, early travelogues, and Santa Clara County histories and reports); maps (e.g., Mexican land grant maps, early city and county maps and surveys, U.S. Department of Agriculture soil surveys, and U.S. Geological Survey maps); photography (both ground-based and aerial), and paintings. We used SFEI's customized Endnote database to catalogue these historical data sources both to avoid duplication and produce bibliographies.

To acquire these sources, we visited local historical archives (Gilroy Museum, San Benito County Historical Society); public libraries (Hollister Public Library, San José Public Library); county offices (San Benito County Public Works Department, San Benito County Recorder's Office, Santa Clara County Surveyor's Office, Santa Clara Valley Water District vault and library), and regional archives (California Historical Society, The Bancroft Library at UC Berkeley, Bureau of Land Management). We also reviewed material available online and conducted searches of over twenty electronic sites and databases, including the Online Archive of California, California Natural Diversity Database, the Searchable Ornithological Research Archive, and the Library of Congress Online Catalog.

We reviewed an estimated 10,000 documents (maps, photographs, and written materials) and acquired full or partial copies of over 2,000. We collected sources of different kinds and from different eras to provide intercalibration or triangulation of landscape features by independent sources (Grossinger et al. 2007a). Each historical source—whether written or graphic, Spanish- or English-language, professional survey or not-to-scale—provided a new perspective on the historical ecology of the area. While we reviewed a large amount of information for this study, the local historical record is voluminous. Additional information will likely be discovered in future years that can contribute to further refinement of our understanding of the local landscape.

INTERPRETATION OF HISTORICAL DOCUMENTS

Accurate interpretation of documents produced during different eras, within differing social contexts, and by different authors, surveyors, or artists can be challenging

(Harley 1989, Grossinger and Askevold 2005). To address these concerns, we used a number of independently produced documents, covering a range of eras and surveyors, to assess the accuracy of each individual document and to promote accurate interpretation of landscape characteristics. This approach, which requires document redundancy, provides the only independent verification of the accuracy of original documents and of our interpretation of them, given absence of replicate samples and predetermined methods (Grossinger 2005, Grossinger and Askevold 2005). Additionally, we conducted background research on the techniques and reliability of the creators of historical records. This included investigation into the reliability of individual surveyors from local histories, comparison between contemporary and modern surveys, and our own assessment of multiple documents by the same surveyor.

We examined historical data for evidence of landscape characteristics prior to significant Euro-American modification. Despite inter-annual and decadal-scale variability, climatic characteristics during the period for which historical data were obtained (1770s-1940s) were relatively stable (Dettinger et al 1998). Since land use was much more variable during this time, we focused on discerning natural from anthropogenic features. We developed a detailed understanding of the temporal trends in land use history and local climate, and were careful to map only features that were clearly not the result of recent land use or extreme climatic periods. Quantitative and narrative descriptions of climatic conditions (floods, droughts, and rainfall) and land use regimes (native management, grazing, dry-farmed and irrigated agriculture) were recorded and compiled. We attempted to document features using multiple sources across the focal time period to assure persistence and accurate interpretation. For example, features whose general presence was indicated by Spanish/Mexican era sources could often be confirmed and mapped in greater detail based upon later American sources, despite surrounding land use changes. Our goal was to map landscape features as they existed, on average, prior to and during the early decades of Euro-American settlement (1770s-1850s). For convenience, we refer to this time period as *circa 1800*.

MAPPING METHODOLOGY

A geographic information system (GIS) was used to collect, catalog, analyze, and display the spatial components of the study area. The relational database component of the GIS allows for storing many attributes about each feature, making a GIS ideal for these tasks. We were able to look through time by assembling maps and narrative information from different periods (fig. 2.1), which allowed us to both assess the different data sources and to better understand change.

The following text first describes the sources and how they were integrated into the GIS, and then discusses how these sources contributed to habitat synthesis and analysis. ArcGIS 9.1 (ESRI) software was used.

Figure 2.1. The geographic information system allowed us to assemble maps and information from different time periods.

Collection of historical spatial data

During data collection, sources were evaluated for their potential usefulness in the GIS. Historical maps, aerial photography, narrative accounts describing a location, and surveyor point data are all potential data layers.

Addition of historical data to the GIS

Sources that were suitable for use in the GIS were added by georeferencing raster maps or by digitizing narrative or survey data. This allowed us to compare historical layers to each other and to contemporary aerial photography and maps.

Accurate historical maps with pertinent land cover information were georeferenced to contemporary orthorectified aerial imagery (USDA 2005), using ArcGIS 9.1 (ESRI). We also developed a continuous historical aerial photomosaic for the study area based upon the earliest available imagery (75 images, USDA 1939) using the Leica Photogrammetry Suite module of ERDAS Imagine 8.7. The photomosaic was particularly useful for identifying residual valley oak savanna, wetlands, and former creek alignments within the pre-urban, agricultural setting.

We developed a GIS database for the Public Land Survey data of the General Land Office, based upon a database and data entry form originally developed by the Forest Landscape Ecology Lab at the University of Wisconsin-Madison. The use of these data is discussed further in Chapter 6. Additionally, the GIS was used to locate and hold textual information gathered from surveyor notes, early explorers' journals, travelers' accounts, and newspaper articles.

Synthesis into a composite map

We synthesized selected georeferenced historical data into a GIS to create a picture of historical habitat distribution and abundance. Reliable historical evidence was found for mapping eight historical habitat or land cover types. These are shown in table 2.1, along with corresponding contemporary wetland and vegetation classes. To record the variations in source data and confidence level associated with different features, we developed a set of attributes to record both historical sources and estimated certainty levels. The application of attributes on a feature-by-feature basis allows users to assess the accuracy of different map elements and identify the original data, serving as a catalog of information sources (Grossinger 2005).

Sherman Day (1806-1884) was Surveyor General of California, a state senator, and superintendent of the New Almaden Quicksilver Mines. Day developed many of the General Land Office Public Land Survey data used in this report. Sherman Island in the San Joaquin Delta and Mount Day in the Sierra Neveda were both named after Day.

Day is pictured with survey equipment in front of a Almaden Mine tunnel in a 1880s photograph by Carleton E. Watkins.

Table 2.1. Habitat "Crosswalk" to Wetland and Vegetation Classifications. NDDB refers to the California Natural Diversity Database (2005); MCV refers to the Manual of California Vegetation (Sawyer & Keeler-Wolf 1995).

	WETLAND CLASSIFICATION AND WATER REGIME (Cowardin 1979)	VEGETATION CLASSIFICATION (NDDB: Holland 1986, MCV: Sawyer and Keeler-Wolf 1995)
Alkali Meadow	Palustrine emergent saline wetland. Temporarily flooded, seasonally to permanently saturated.	Saltgrass alliance, Alkali sacaton alliance, Ashy ryegrass alliance, Creeping ryegrass alliance (MCV); Alkali Meadow (NDDB)
Wet Meadow	Palustrine emergent wetland. Temporarily flooded, seasonally to permanently saturated.	Ashy ryegrass alliance, Creeping ryegrass alliance (MCV); Valley wild rye grassland (NDDB)
Valley Freshwater Wetland	Palustrine persistent emergent freshwater/saline wetland. Temporarily to seasonally flooded, permanently saturated.	Bulrush series (MCV)
Seasonal Lake/Pond	Palustrine persistent emergent freshwater/saline wetland. Seasonally flooded, permanently saturated.	Bulrush series (MCV)
Perennial Freshwater Pond	Permanently flooded.	Bulrush series (MCV)
Willow Grove	Palustrine forested wetland. Temporarily flooded, permanently saturated.	Arroyo willow alliance (MCV)
Oak Savanna/Woodland	Intermittently flooded, saturated at depth.	Valley oak alliance (MCV); Valley Oak Woodland (NDDB); Valley oak/grass association (Allen et al. 1991)
Grassland	-	Ashy ryegrass series (MCV)

Certainty levels were assigned based upon qualitative and quantitative assessment. Our confidence in a feature's interpretation, size, and location was assigned on a relative scale based upon the number and quality of sources, and our experience with the particular interpretation (table 2.2; Grossinger et al. 2007a).

Comparison to present-day conditions

For the Santa Clara County portion of the study area, we were able to use recent land cover mapping by Jones and Stokes (2006) to compare historical and modern spatial extent of several habitat types. Corresponding classes were selected based on narrative descriptions of the modern land cover classes (Jones and Stokes 2006). For the San Benito County portion of the study area, we used mapping by the National Wetlands Inventory (USFWS 2007). We also compared historical land cover patterns to existing land use to determine potential restoration opportunities at the conceptual level, and conducted limited field surveys to confirm landscape changes and identify the residual or recovered features at these sites. Additional assessment of contemporary and projected future conditions was beyond the scope of this project, but would be important to evaluate site-specific feasibility of conceptual restoration strategies identified here.

Table 2.2. Certainty level standards.

Certainty Level	Interpretation	Size	Location
High/ "Definite"	Feature definitely present before Euro-American modification	Mapped feature expected to be 90%-110% of actual feature size	Expected maximum horizontal displacement less than 50 meters (150 ft)
Medium/ "Probable"	Feature probably present before Euro-American modification	Mapped feature expected to be 50%-200% of actual feature size	Expected maximum horizontal displacement less than 150 meters (500 ft)
Low/ "Possible"	Feature possibly present before Euro-American modification	Mapped feature expected to be 25%-400% of actual feature size	Expected maximum horizontal displacement less than 500 meters (1600 ft)

TECHNICAL ADVICE AND REVIEW

We recruited advice and review from experts in a number of different fields, including ecology, geomorphology, geology, archaeology, and landscape history. Members of the Technical Advisory and Review Group provided comments on the draft report and/or guidance and review on specific topics during the course of the project.

Technical advisory and review group

Timothy Babalis, Landscape Historian, National Park Service

Josh Collins, Wetland Scientist, SFEI

Andy Collison, Fluvial Geomorphologist, Philip Williams & Associates

Frank Davis, Landscape Ecologist, UC Santa Barbara

Todd Keeler-Wolf, Vegetation Ecologist, California Department of Fish and Game

Randy Milliken, Anthropologist

Randy Morgan, Botanist

Janet Sowers, Fluvial Geomorphologist, William Lettis & Associates

3 LAND USE HISTORY

Above. Henry Miller's Bloomfield Ranch, near Gilroy, ca. 1890 (Unknown ca. 1890a). *Below.* Label from canned peaches, Filice & Perrelli Canning Co. Inc. (ca. 1940). (Courtesy of the California Room, San José Public Library (top) and History San José (bottom)).

LAND USE HISTORY

This section reconstructs the general patterns of land and water use in south Santa Clara Valley over the past 250 years. Since human land use alters the landscape, it is essential to understand the timing and extent of major historical land uses in order to understand the region's historical ecology.

South Santa Clara Valley has experienced a series of massive cultural shifts since 1769, including Spanish colonization, American statehood, and more recently, rapid urban and suburban expansion. Each of these cultural transformations has led to dramatically different ways of using the local landscape.

Within each of these major eras, land use patterns have shifted in response to regional economic drivers (the collapse of Mission San Juan Bautista or the Gold Rush), changes in technology (electricity-driven groundwater pumping or the arrival of the railroad), and variations in climate (dry or wet series of years; fig. 3.1). Mission San Juan Bautista brought the first cattle to the region in 1797, while the 1864 drought nearly destroyed the industry. The drilling of artesian wells in the 1870s allowed for the cultivation of irrigated crops, such as orchards and alfalfa, while the railroad connection between Gilroy and San José in 1869 helped provide a market for the fruit and cheese produced.

Each shift in land use has affected different aspects of the habitats and functions of the native landscape. For example, early dairy farms (with their requirement for rich pasture and access to water) provided incentive to clear lush willow groves, but did not directly conflict with valley oak lands. Nineteenth-century orchards (planted on well-drained alluvial soils) caused the clearing of oak lands, but left most sycamore alluvial woodlands intact. Population growth often paved the way for channel modifications as bridges were built and creeks straightened to reduce flooding.

Useful information for historical ecology includes the location of historical settlement sites, the alignment of roads, agricultural trends, place-name histories, drainage efforts, and the use of water resources. In particular, regional agricultural trends help elucidate soil texture and type (e.g., seasonally wet areas tend to remain in hay or grain for longer, crops such as sugar beets and asparagus are more tolerant of salt-affected alkali meadows and salt marshes, and alfalfa has high water requirements). Irrigation histories illuminate which creeks ran dry during the summer, and which areas seasonally flooded. Historical settlement sites often indicate areas with perennial access to water. Road alignments can reveal marshy areas circumvented by roads, creek channels where the road jogged (e.g., Lover's Lane at Pacheco Creek), and channel geometry through bridge placements. Place names such as Soap Lake, Uvas Creek, El Roble School, and Terentak also offer clues to the nature of the native landscape.

"The whole valley was densely timbered, but the gigantic oaks had to make way for the plow, to be succeeded by fields of grain, and these were followed quickly by vines and fruit trees..."

— HARRISON CA. 1888, DESCRIBING UVAS VALLEY

South Valley's position as both the southern end of Santa Clara Valley and as an inland portion of the Monterey Bay watershed has been a key influence on the region's history. It also encompasses a major prehistoric and historical route, Pacheco Pass, connecting the Bay Area and coast to the Central Valley, and has long been a corridor between these areas. Trends in development often followed those of the northern Santa Clara Valley, but with some delay. Concurrently, indigenous villages, the Mission San Juan Bautista, and, later, the towns of Morgan Hill, Gilroy, and Hollister established local spheres of influence.

The history of south Santa Clara Valley can be divided conceptually into six general eras, each characterized by differing cultural contexts and land management approaches. These eras are described in detail in this chapter.

NATIVE LAND MANAGEMENT ERA (PRE-1769)

South Santa Clara Valley has probably been inhabited for over 13,500 years (Goebel et al. 2008). Yet the earliest direct evidence for human presence dates only to 4,200 years ago, due to the ongoing obliteration of soil surfaces through geomorphic processes (Hildebrandt and Mikkelsen 1993, Rosenthal and Meyer 2004). Until about 2,500 years ago, populations were non-permanent, and seasonally moved out of South Valley to take advantage of resources in coastal and inland California (Milliken et al. 1993).

At the time of Spanish contact (1769), the area was home to speakers of dialects of the Ohlone (also called Costanoan) language family. At least two separate groups, the Ausaimas and the Uñijaimas, held the valley portions of the Pajaro River. The Ausaimas occupied the Bolsa, including the San Felipe Lake area, Tequisquita Slough, and lower Pacheco Creek. The Uñijaimas lived along the western edge of south Santa Clara Valley and foothills north from the Pajaro River up toward modern Gilroy. Exact territorial boundaries between the two tribes are unknown. Neighbors included the Mutsun to the south (at modern San Juan Bautista), the Tomoi to the east (probably sharing a boundary around Bell's Station/Cedar Creek), and the Matalan to the north (Milliken et al. 1993).

Early explorers in the area described an extensive trail network over much of the study area, and noted the locations of large villages (e.g., Palou 1774 in Bolton et al. 1930, Crespí 1772 in Crespí and Bolton 1927). In 1774, Palou affirmed the strong cultural presence in these newly "discovered" lands, writing that the explorers encountered "at every step their [indigenous] trails very well worn" in the San Benito Valley and on the hills around it.

While historical sources such as Spanish explorers' journals, San Juan Bautista mission records, and ethnographic information do not provide a comprehensive picture of pre-Mission life, they do offer some details on population distribution and cultural practices in the region. They reveal the variety of ways native populations engaged with the landscape, including fishing in riverine, groundwater-fed pools, fishing from rafts and boats in large ponds or lakes, hunting and collecting acorns, seeds, and other plants.

> In 1770, Fages observed that the Ohlone hunted waterfowl on San Felipe Lake: *"[They] went about with two little rafts, hunting ducks on the pool."*

These sources also provide a general picture of where Ausaima, Uñijaima, and Mutsun villages and other sites with significant seasonal use may have been. The names of these sites can supply information about the local ecology. Sites were located on the valley alluvial plain, in the foothills, along creeks, and on the shore of San Felipe Lake (Hildebrandt and Mikkelsen 1993). Just to the south of the study area was the Mutsun village of Terentak ("place of small waters" or "the spring"), now San Juan Bautista (Harrington 1929, Ketchum

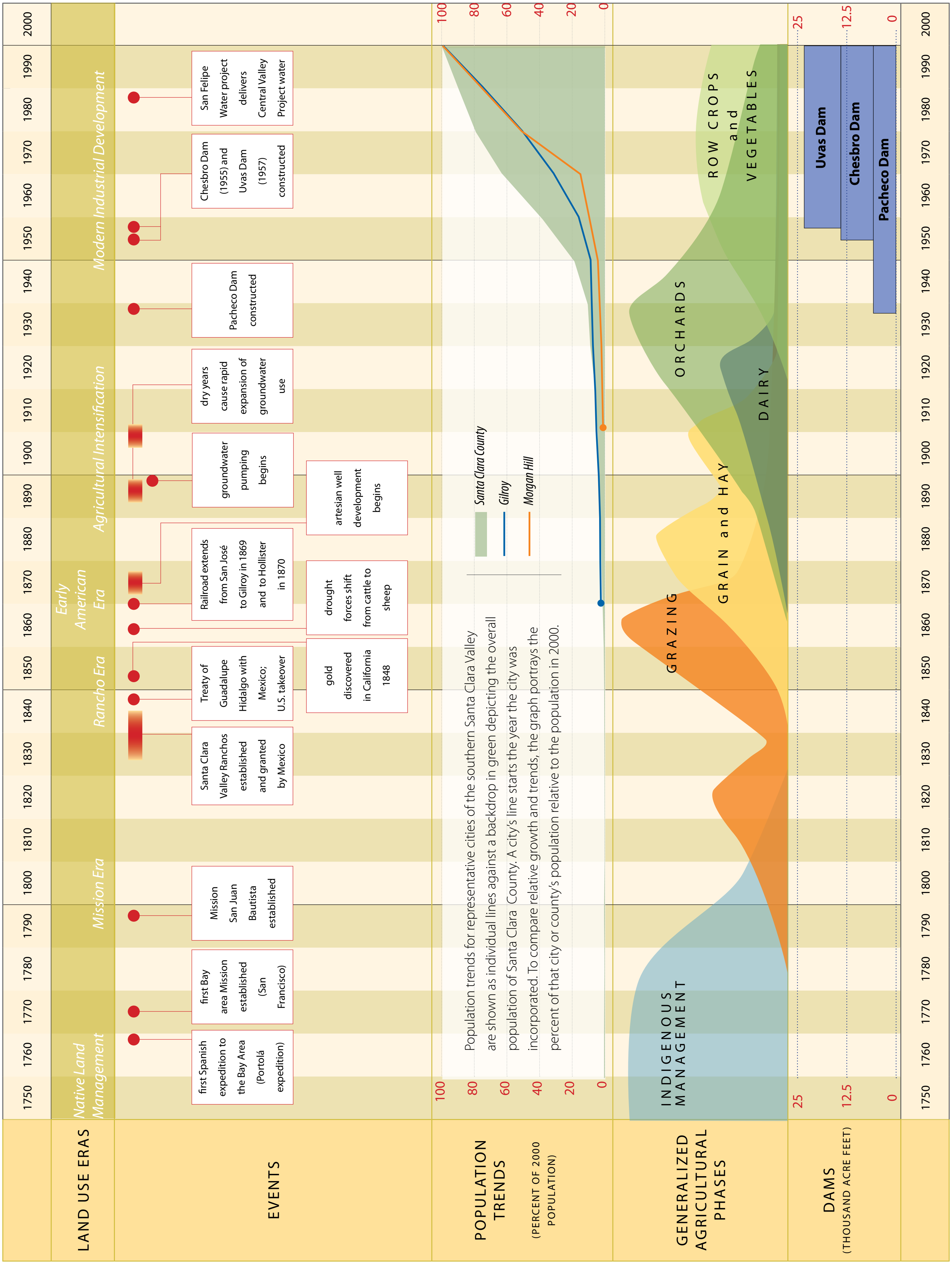


Figure 3.1. Timeline depicting land use trends in south Santa Clara Valley over the past 250 years, including population growth, agricultural phases, major water storage development, and other significant events affecting land use.

pers. comm.). An important Mustun site (possibly also used by Uñijaima) was located at the boundary between Mutsun and Uñijaima territories, just above the confluence of the San Benito and Pajaro rivers. Mutsun dancing ceremonies took place here, and for this reason it was called Juristak, or "place of the big head...what the dancers are called with their large feather head dresses" (Ketchum pers. comm.).

In the Bolsa/Pacheco Creek area was a large Ausaima village, Poitoquix, located in the general vicinity of Dunneville (possibly on south bank of Pacheco Creek or north bank of Tequisquita Slough; Milliken et al. 1993). The Bolsa south of San Felipe Lake was known as Welelismo ("place of the salamanders"; Ketchum pers. comm), suggesting the presence of seasonal freshwater ponds. Another Ausaima village was noted by Fages in 1770 (Fages and Bolton 1911) at the head of San Felipe Lake, on the edge of the tule:

> At the place where they [reed patches] end there was a very large pool, and at the head of this a village of heathen, in which we saw about fifty souls...two of them hastened off across the plain to inform two very large villages of our passing; these villages were in sight, midway of our march...

The head of this "very large pool" was possibly around the entrance of Tequisquita Slough into San Felipe Lake, or to the northwest of the lake around what was to become the location of the Sanchez soap house (cf. Hildebrandt

SOUTH SANTA CLARA VALLEY LAND USE TIMELINE

1769: First Spanish explorers enter Santa Clara Valley as part of Portolá expedition

1797: Mission San Juan Bautista founded

1834: Secularization of the Mission system; rapid decline of Mission San Juan Bautista

1848: Start of the Gold Rush

1862-1864: Drought, plus wet season of 1861-1862, facilitates transformation of valley from open cattle grazing to wheat and cattle

1868: Hollister founded

1869: Railroad expands to Gilroy from San José, opens new markets for perishable products (fruit, dairy)

1870: Railroad expands to Hollister

1870: Gilroy incorporated

1870s: Artesian wells begin to be dug in great numbers

1874: Millers Canal completed, connecting San Felipe Lake to the Pajaro River

1874: San Benito County established from inland portion of Monterey County

1906: Morgan Hill incorporated

1938: South Santa Clara Valley Water Conservation District organized

1939: Pacheco Lake built by the Pacheco Pass Water District (6,150 ac-ft)

1955: Chesbro Dam (8,090 ac-ft) built by South Santa Clara Valley Water Conservation District

1957: Uvas Dam built (9,950 ac-ft) built by South Santa Clara Valley Water Conservation District

1970s: Caltrans Llagas Creek gravel removal and flood channel project

1987: San Felipe Water Project delivers first Central Valley Project water to area and Mikkelsen 1993, Ketchum pers. comm.). The other "two very large villages" mentioned – possibly Ausaima, possibly Uñijaima – were located in the lower Gilroy/ Bolsa area. At least two additional Ausaima villages are mentioned in Mission records, but their locations are unknown (Milliken et al. 1993). In 1772, Crespí (Crespí and Bolton 1927) also recorded small villages in the Bolsa area using the area's resources: "the land is very good, with abundant pasturage, and it has innumerable large lagoons of fresh water and three or four villages of heathen, who, by means of rafts, catch a great deal of fish in the lagoons…on the plains not a tree is to be seen, though they are all covered with grass."

A number of Uñijaima villages were located north of the Pajaro River (Milliken et al. 1993, Ketchum pers. comm.). They included Tipisastac (likely in the La Brea area north of the confluence of the Pajaro and San Benito Rivers), Thithirii (in the Carnadero area south of Gilroy), Kululistak (just north of Gilroy), and Chitactac (fig. 3.2; along Uvas Creek west of Gilroy). Anza passed one of these villages in 1776, possibly Thithirii or another village in the Old Gilroy area: "we saw a village of seventeen huts…" (Bolton et al. 1930).

The largest recorded site was a village of thirty thatched houses and an estimated 300 people, located near a stream, a grove, and a large pool (Crespí and Bolton 1927; Palou 1774, in Bolton et al. 1930):

> …we came to a large grove, heavily grown with cottonwoods, sycamores, willows, and briars, and within it there was a large village…near the village we saw a large pool or water, and judging from the course of growth of trees there might be a running arroyo there. (Palou 1774, in Bolton et al. 1930)

The exact location of this village is unknown. It may have been the Ausaima village of Poitoquix around Dunneville, or another village located west of Tequisquita Slough in the lowlands just north or south of the Pajaro River near its confluence with Llagas and Carnadero creeks.

The Spanish explorers, as well as subsequent early travelers in South Valley, noted abundant evidence of fire management in the area, where controlled burning was used to manipulate vegetation patterns and maintain or increase productivity. Surveyors and explorers remarked on hazy skies and burns in the Santa Clara Valley: Costansó, traveling with Portolá in 1769, records that the whole of the valley was "impassible on account of the absence of pasture, which the natives had burned" (Costansó and Browning 1992). These fires were often mistaken for accidental blazes by early travelers.

Given the ubiquity of fire in early descriptions, it is clear that tribes in this region employed fire with great regularity and over enormous geographic areas. Based on local knowledge and studies of other regions, it is likely that fire intensity and frequency varied for different habitats and objectives (e.g., Stephens and Fry 2005). However, in general these activities likely contributed to more open woodland and savanna patterns, encouraging increased seed yields and clearing brush land for acorn harvest (Lewis 1973, Anderson 2005). Coppicing and selective harvesting likely affected the growth patterns of valued species such as willows (Anderson 1999).

The intensity of native management underwent a rapid decline in the early 19th century. The combined effect of epidemics and relocation led to the end of native management practices across the region. As the local Mutsun Ohlone population became increasingly incorporated into the life and livelihood of the San Juan Bautista Mission (established 1797), native land management practically ceased.

MISSION ERA (1769-1834)

The first group of Spanish explorers to enter the Santa Clara Valley arrived under the direction of Don Gaspar de Portolá in November 1769. The San Juan Bautista mission was founded in 1797, twenty years after the Mission Santa Clara de Asis and the Pueblo of San José were founded in upper Santa Clara Valley, about 55 km

Figure 3.2. Bedrock mortars along the perennial portion of Uvas-Carnadero Creek are evidence of Ohlone use of the Chitactac site, now part of Chitactac-Adams County Park. (Photograph by Ed Ketchum)

(35 mi) to the northwest. Mission San Juan Bautista (fig. 3.3) provided the last link along the trail (the precursor of El Camino Real) connecting San Francisco and Monterey. With the founding of the mission, livestock were introduced into the lower Santa Clara Valley, most notably cattle and sheep.

Though the San Juan Bautista mission cultivated orchards, including olive, apple, and peach trees in the uplands above the Mission, the main livelihood of the Mission was cattle- and sheep-raising. While Beechey ([1831]1941) describes the orchards, vegetable gardens, and cattle of the Santa Clara Mission in some detail, his only observation of agriculture and ranching around

Figure 3.3. An early view of Mission San Juan Bautista taken by Carleton Watkins. (Watkins ca. 1876, courtesy of the Franciscan Missions of California Photographs Collection, The Bancroft Library, UC Berkeley)

San Juan Bautista is that "in the neighboring meadows there were several large herds of cattle; and the geese settled there in flocks, as at the mission of Santa Clara."

Rangeland needed to provide both ample forage and a water source in order to be viable cattle grazing land. Many of the low-lying areas in South Valley (which would later become dairies, for similar reasons) offered both. Lush wet meadows (and later wetland areas with artesian resources) provided abundant food and water for Mission cattle.

> *"In the neighboring meadows there were several large herds of cattle; and the geese settled there in flocks, as at the mission of Santa Clara."*
>
> – BEECHEY, NOVEMBER 1826

Mission San Juan Bautista's stock were pastured on their holdings which included much of the southern portion of the Santa Clara Valley (south of the current Santa Clara county line) as well as upland holdings around the upper Pajaro River and Pacheco Creek (Broek 1932). Records from 1816-1825 show that the Mission owned about 10,000-11,000 cattle and between 9,500-15,000 sheep (though this included Mission lands not in the study area; Engelhardt 1931). In 1825, for example, nearly 7,000 sheep were raised on the ranches San Felipe, Brea (around Sargent), and Carneros alone (Milliken n.d.). In 1816, Mission San Juan Bautista's peak year of stock holdings, the Mission had a stocking density of approximately one head per every 1.8 ha (4.5 ac; Bowman 1947). (Moderate stocking density is considered to be one cow in 4 ha/10 ac; Bancroft [1890]1970.)

RANCHING AND THE RANCHO ERA (1834-1864)

The secularization of the mission system in 1834 changed landholding patterns across the Santa Clara Valley as lands held by missions were granted to prominent Mexican residents as land grants. The first land grant in the valley taken from Mission San Juan Bautista was Ausaymas y San Felipe (from Tequisquita Slough up to Pacheco Creek) in 1833. Presumably because of alkali deposits and sparse vegetation, this land was considered marginal anyway, and residents of the area noted that "the Mission had granted said lands to your petitioner because said Mission did not want them" (Unknown 1852). Over the next nine years, however, the Mission was gradually stripped of most of its holdings, including the most lucrative, leaving it only some valley land directly surrounding the Mission (Broek 1932; table 3.1).

Stripped of land and thus livelihood, the Mission system collapsed nearly overnight. Where travelers Beechey ([1831]1941) and Robinson ([1846]1947) were served chocolate for breakfast in 1826 and 1829, a visitor in 1840 found that the Mission was in such disrepair that it was "as though [it] had ceased to exist" (Rubio 1840, in Engelhardt 1931). Wise (1850) found "a detestable spot... more than half in ruins, and rapidly crumbling to the ground." In 1836, the Mission recorded holdings of only 869 cattle and 4,120 sheep (Engelhardt 1931). By 1842, they had none (Bancroft 1888, Broek 1932).

> *"An immense plain, quite level, that measures 16 leagues long by 6 or 7 wide, separates San Juan from the pueblo of San José. This country is almost uninhabited, only four small ranchos being found along the route...[Gilroy] has about 100 occupants and a large amount of live stock and seems destined to become an important center with its abundance of water, plains, and excellent farming lands."*
>
> – DE MOFRAS, 1844

As the Mission's stock dwindled, private stock holdings swelled, and cattle density (in many places) likely increased. Land no longer held by the Mission went into the hands of a few large landowners, who used their

Table 3.1. Lands granted from San Juan Bautista Mission territory (from Broek 1932).

Date of Grant	Name of grant	Area granted (Mexican square leagues)	Acreage confirmed in U.S. District courts
1802 (early private holdings)	Las Animas	6	24,066
1833	Ausaymas y San Felipe	3	11,744
1835	Llano del Tequisquita	4	16,016
1835	Juristac	1	4,482
1836	San Joaquin	2	7,425
1839	Santa Ana y Quien Sabe	11	48,822
1839	San Justo	8	34,619
1840	Bolsa de San Felipe	1.5	6,795
1842	Lomerías Muertas	1.5	6,660

vast holdings to graze cattle and cultivate small home gardens. De Mofras ([1844]1937a) observed that the land between San Juan and the northern Valley was "almost uninhabited," the only settlement of note being that of John Gilroy (now Old Gilroy, located on the Yolo silt loam deposited by Llagas Creek), which then contained about 100 inhabitants and "a large amount of livestock." In 1852, Pacheco kept between 8,000-10,000 cattle and horses on ranchos Bolsa de San Felipe and Ausaymas y San Felipe (Taboas 1852). Mariano Castro kept about 15,000 cattle on the Las Animas rancho, more cattle than were kept on all the Mission's holdings before secularization (Pico 1852). This suggests a minimum stocking density on the Las Animas rancho of 0.6 ha (1.6 ac) per cow, a dramatic increase in density from the Mission era. Similar increases have been noted in northern Santa Clara Valley (Grossinger et al. 2006).

California's transition from a Mexican to an American territory, and the start of the Gold Rush in 1848, signaled the end of the relatively brief Rancho era. It marked the beginning of fragmentation of the large Mexican land grant system as gold-seekers-turned-settlers challenged rancheros' large land holdings. While most new American settlers at first maintained the Mexican land use pattern of stock raising and subsistence farming, the vast cattle ranching operations of the 1830s and 1840s soon began to disintegrate.

Still, the initial extent of fragmentation of these large tracts of land was not nearly as acute in South Valley as in the northern Valley, where rich land, proximity to markets, and San José's location on a main route to the Gold Country drew more settlers and thus brought more challenges to the Mexican land grant system. Whereas in the northern and central Santa Clara Valley only 48,500 ha (120,000 ac) out of 90,200 ha (223,000 ac) claimed were confirmed to Mexican claimants rather than Americans (a little more than half), nearly all of the claims of South Valley rancheros were confirmed in the Mexican claimants' favor (about 53,400 ha/132,000 ac out of 55,200ha/136,500 ac; Broek 1932).

This disparity in settling patterns between North and South Valley provided impetus for an earlier transition away from stock-raising into agriculture in North Valley, exacerbating the divergence in land use patterns between the two areas that continues today. Brewer, traveling in what is now the Morgan Hill area in 1861, observed:

> ... it is here all covered with Spanish grants, so is not cultivated, but near San Jose, where it is divided into farms, it is in high cultivation; farmhouses have sprung up and rich fields of grain and growing orchards everywhere abound. But near our camp [at 21 mile house, in present Morgan Hill] it lies in a state of nature, and only supports a few cattle. One ranch there [San Francisco de las Llagas] covers twenty-two thousand acres of the best land in the valley—all valuable. (Brewer [1930]1974)

This pattern was even more pronounced in the southernmost part of Santa Clara Valley (then Monterey County), where the 1850 Census described "ranches of unknown extent, even to their owners...covered with vast herds of cattle and horses, whose number also is generally unknown to the proprietors. The extent of agriculture is the raising of a small patch of beans" (U.S. Census Bureau 1850, in Roddy 1995). This slower rate of agricultural intensification in South Valley limited the pace of habitat modification.

AGRICULTURE AND THE EARLY AMERICAN ERA (1864-1874)

Climatic factors and advances in infrastructure brought about the end of the open range cattle era in much of South Valley in the 1860s. The drought of 1862-1864 decimated cattle ranches all over California, and over one million cattle starved or were slaughtered in the state (MacGraw 1961). Meanwhile, the connection of Gilroy (1869) and Hollister (1870) to big-city markets through the Southern Pacific railroad opened up new markets for South Valley farmers.

Drought and the cattle industry

Southern Santa Clara Valley was hit hard by the droughts of 1862-1864, and thousands or cattle starved or were killed. The change was so abrupt that by 1868, only a few years later, one observer noted that "there are very few cattle raised in the county, it being so generally under cultivation with grain and fruit" (Cronise 1868). While this was undoubtedly more true for North Valley than South Valley, it is indicative of the sweeping changes that had occurred.

The drought did not eliminate cattle ranching from South Valley (fig. 3.4). But it did mark the beginning of the end of the dominance of open-range, beef cattle-raising in many parts of South Valley as ranchers in areas with richer soils turned to sheep, wheat, and dairy cattle. It changed the dynamic of cattle-ranching and shifted the balance of land use types in the region. Whereas before 1864 cattle were raised mainly for beef and hides, after the drought most valley-floor cattle were dairy cattle, raised in areas with naturally wet meadows and artesian flow. And while before 1864 stock raising was the single significant land use on ranchos including the productive valley floor land, after the drought larger cattle operations were mainly relegated to upland areas, while more lucrative uses such as dairies and wheat

Figure 3.4. "Dunne Ranch, Gilroy." This image, taken by photographer Andrew Hill (ca. 1890) shows cattle standing on a creek on the Dunne Ranch (Llagas Creek watershed). It was likely taken not long before the area's subdivision in the early 1890s. Because of its late subdivision, the area remained grazing land far later than similar land in northern Santa Clara Valley or on alluvial soils around Gilroy. (Courtesy of the California Room, San José Public Library)

became prominent in valley floor areas with richer soils. Those places on the valley floor that remained grazing land were more marginal lands with poor soil, poor drainage, or both - most notably, the Bolsa. Cattle that remained were often grazed in the uplands for the winter, then pastured in the Bolsa during the dry season (Broek 1932).

In 1929, long-time resident Isaac Mylar recalled the devastation to cattle in the Bolsa during the 1864 drought: *"...there was a slough [Tequisquita] that lead [sic] into Soap Lake. This slough would be lined with the decaying carcasses of cattle who, too weak to pull themselves out of the mud, died there. They died by the hundreds, whilst striving to reach some tule, or some wisp of grass, that they saw growing on the banks of the slough."*

For a brief period from around 1864 until the 1880s, intensive sheep raising overtook cattle raising as the dominant land use throughout northern San Benito and southern Santa Clara counties, in part because of their greater tolerance of drought. This was consistent with a wider statewide trend: while the 1850 California census recorded under 20,000 sheep, by 1876 (the peak of the industry) there were over 6,400,000 sheep in the state being raised for meat and wool (Johnston and McCalla 2004). Near Madrone (now northern Morgan Hill) in 1874, one traveler saw such a large flock of sheep that from a distance she mistook them for a crop, asking her companion "what that was growing off to the left" until she saw them moving (Likins 1874). Further south, a resident of the Soap Lake area recalled that at the time his mother was born in 1885, the perimeter of Soap Lake was all sheep country (Fought 2000). In the Hollister area, the largest sheep herd owners, W.W. Hollister and Flint Bixby & Co., herded around 70,000 sheep in the area (San Jose Mercury 1864). By the end of the 1880s, however, references to large flocks of sheep in south Santa Clara Valley seem to disappear.

"[The Gilroy Valley] produces a great many sheep. I saw more thousands than I should like to state. It is enough to say that mutton is not scarce about the town of Gilroy..."

- PHILLIPS 1877

"A large flock of sheep said to embrace from 1500 to 3000 sheep, belonging to Dunn [sic] & Donnelly and which had been driven within an enclosure for protection, were all drowned by the rising of the Pacheco."

- SAN BENITO ADVANCE, NOVEMBER 20, 1875

Railroads and wheat

In addition to the drought of the early 1860s, the second factor that facilitated the transition from cattle grazing to agriculture was the coming of the Southern Pacific railroad, which reached Gilroy in 1869 and Hollister in 1870. The railroad opened up new markets for South Valley farmers, who before had no timely way to transfer perishable goods to markets around San José and San Francisco. Cronise (1868) reported that "[productive] land extends beyond Gilroy, thirty miles south of San José, but it is not generally cultivated, as it does not prove renumerative to haul produce to market by teams from that point. When the railroad to Watsonville is constructed, many thousands of acres in this district will be cultivated, which are now used for grazing."

By around the 1860s, wheat had begun to be planted on a large scale on productive valley floor lands (MacGraw 1961). Cronise (1868) notes, perhaps somewhat hyperbolically, "from San José to Gilroy...the valley in the summer forms an almost unbroken wheat field." The formation of the city of Hollister in 1868 further spurred the transformation of productive valley land in South Valley, especially around the Gilroy and Hollister areas, from largely grazing land to largely wheat fields.

Wheat fell out of favor nearly as abruptly as it had fallen into it, and production peaked around 1874 or 1875 (Guinn 1910, Broek 1932). By the mid-1870s, waning crop yields coupled with low profits for wheat relative to potential revenues with other crops (e.g., hay and, increasingly, fruit) and steep shipping prices generated a sharp drop in wheat production on both sides of the county line (McCallum 1974). This change relegated wheat to the valley periphery, away from high-yield soils around Hollister and north of Gilroy.

Though it ceased to be the dominant crop, wheat continued to be grown in large quantities even into the 1890s. As late as 1888, wheat and barley were the principal products of the Gilroy area, though the fruit industry was more profitable and was rapidly superseding wheat (Harrison ca. 1888).

"A stranger visiting Hollister, especially during haying season, is struck with the sight of railroad trains of hay-loaded cars, hay-loaded wagons and the loading and unloading, by block and tackle, of endless bales of hay, hay, hay."

– LILIENCRANTZ 1956

In Hollister, hay took over as the preferred crop, with the Bolsa providing a particularly important source. Hollister soon became known as "Hay City" (Unknown 1975(?)). Until the end of World War I, hay was a primary crop in Hollister (McCallum 1974). But as cars and tractors replaced horses for transport and farm use, the hay market began to decline (Broek 1932).

ORCHARDS, DAIRIES, AND WELLS: AGRICULTURAL INTENSIFICATION (1874-1930)

Artesian wells

By the early 1870s, farmers, ranchers, and dairymen with land in the artesian belt generally defined by the Bolsa floodplain began to drill artesian wells – lots of them. The most notable section of the artesian belt was located in the San Felipe district northeast of the Bolsa, where, as a member of the San Benito Well Boring Company bragged in 1889, they could "strike artesian water anywhere between San Felipe and Poverty Hill [near the Hillcrest/Sunnyslope area of Hollister]" (Hollister Free Lance 1889). By 1886, there were over 75 artesian wells in the small San Felipe district alone (Hollister Free Lance 1886b). By 1888, there were at least 150 artesian wells in the Gilroy area and another 119 in northern San Benito County (fig. 3.5; Harrison ca. 1888; U.S. Census Bureau 1894, in Kilburn 1972).

Free-flowing artesian wells provided ample water for crop irrigation. The small but well-positioned San Felipe region, formerly dominated by willow groves, was quickly made into the favorite region of the area: "San Felipe is a conspicuous spot, because it is evergreen, and during the dry seasons presents a marked and pleasing contrast to the brown and dusty fields and hills which one sees everywhere else" (Harrison ca. 1888).

Since wheat was dry-farmed, and "never irrigated, as more profitable crops may be grown with the same amount of labor" (Shortridge [1896]1986), the development of groundwater supplies and irrigation quickly made wheat a less lucrative option on the valley floor alluvium. Wheat production peaked in the mid-1870s, just as the number of artesian wells in South Valley began to swell. Wheat and other grains became largely relegated to the valley margins and foothills. In its place came two crops largely dependent on irrigation from artesian wells: alfalfa (to feed dairy cows) and orchards.

The railroad had made new markets for fruits and dairy products more accessible to the previously more remote Gilroy and Hollister areas. Dairying and horticulture thrived in places where the presence of artesian water intersected with access to quality soils, such as the San Felipe district, around Hollister, and around Old Gilroy (east of present-day Gilroy near Llagas Creek).

Figure 3.5. "Artesian wells on the Ausaymas Ranch, drilled June 1912." Since the 1870s, groundwater has been an important source of water for crop irrigation in South Valley. (Unknown ca. 1912c, courtesy of the San Benito County Historical Society)

Dairies

Beginning in the 1860s, the gradual draining of lowland areas in South Valley and development of an artesian water supply facilitated the growth of thriving dairy regions in the Gilroy and San Felipe districts. The low-lying land south of Gilroy, around the confluences of the Llagas and Carnadero with the Pajaro, was called "willow land" (Coffin 1873). Occupying lands with relatively high groundwater but without excessive clay content, the willow lands were particularly valued for agricultural production. Artesian wells, lush vegetation, and seasonal flooding were hallmarks of these swampy areas (Coffin 1873, Harrison ca. 1888), covering large swaths of the region around lower Llagas Creek, Carnadero Creek, and the Pajaro River.

> *"In the great district where these various streams converge, within a radius of several miles, there is a great artesian basin."*
>
> – SHORTRIDGE 1896

The rapid and early "transformation of the willow patches… into veritable gardens" (Shortridge [1896]1986) beginning in the early 1860s was considered a major accomplishment. One of the main uses of this land was to pasture dairy cattle: "Some of the land is low and in the rainy season partially covered with water. This is used for pasturing dairy stock" (Harrison ca. 1888).

One of the first dairies in South Valley was founded south of Gilroy in 1863, on drained willow land on Carnadero Creek just north of where Tar Creek enters it (Shortridge [1896]1986, Broek 1932). Shortridge describes how Samuel Rea reclaimed "the rich Delta land at the mouth of Carnadero Creek" in 1863, taking advantage of the low-lying grassland abundant in the area: "The land was at that time covered with a dense growth of willows. Mr. Rea cleared the land and opened a channel for Carnadero Creek...As Mr. Rea's land was moist, and furnished with an abundant supply of native meadow grasses, he went into the dairy business..."

By 1870, Rea's dairy was one of many in the Gilroy area to produce cheese and butter from excess milk. In 1881, there were approximately 3,000 dairy cows in the Gilroy district (Broek 1932; fig. 3.6). By 1896, Shortridge writes: "Gilroy's principal product is cheese, the succulent grasses which flourish along the creeks and in the low lands at the confluence of the several streams in the center of the valley, having early brought about the development of the industry. Gilroy now produces 1,300,000 pounds of cheese per annum, which is about one-fifth of the entire product of the State."

On the San Benito County side of the valley, dairy production began slightly later, around the mid-1870s. By 1879 San Benito County had significant dairy production centered around the San Felipe district northeast of the Bolsa, where alluvial Yolo silt loam deposits from the

Figure 3.6. Furlong Ranch, east of Gilroy (ca. 1890). Harrison (ca. 1888) described the Furlong Ranch around the same era: "A short distance west of Old Gilroy and on the road to San Felipe, is one of the prettiest farms in the State…Nearly all of the low land is covered with rye grass, which is well adapted to wet land, growing even in the water. It is nutritious, stock like it, and it makes good hay…The leading feature of this farm is dairying, the dairy consisting of 135 cows…Twenty acres are planted in fruit. There are six artesian wells on the farms, five of which are under 80 feet in depth…The green fields of rye grass, upon which sleek horses and cattle are grazing, the handsome residence and numerous out buildings, the cottages of the dairymen, all combine to form a picture which it would be impossible to fully represent in a wood engraving." (Unknown ca. 1890b, courtesy of the Gilroy Museum)

Pacheco Creek watershed provided rich, moist, alkali-free soil (Cosby and Watson 1927b; fig. 3.7). Well established as a dairy region by 1881 (cf. Pacific Coast 1881b), peak cheese production was reached in 1889 and peak butter production in 1899 (Unknown 1975(?)). By the turn of the century there were six large dairy factories simultaneously in operation in the tiny San Felipe district (including one owned by a man nicknamed "Butter" Brown who lived "in the swamp"; Williams 1968a,b).

Orchards

Some of the first fruit trees in San Benito County (cherries) were planted in the San Felipe district, likely in the late 1860s (Anderson n.d.). As artesian water use developed, the prevalence of fruit trees began to increase in South Valley on productive, well-drained soils around Gilroy and Hollister where wheat (and earlier, cattle ranching) had once dominated (Jacobson 1984). This land use conflicted more directly with oak savannas and woodlands than cattle grazing and grain culture had, as orchards were typically planted at a density of 267 trees/ha (108 trees/ac; or as much as 474 trees per hectare/192 trees per acre; Shortridge [1896]1986).

In 1873, the area east of Gilroy near Llagas Creek was described as predominantly grain fields, with orchards planted near the houses: "A most charming section of country, with neat farm houses scattered here and there, surrounded with orchards, vineyards, and shade trees, and large fields of waving grain extending as far as the eye can reach" (Coffin 1873). By 1888, while wheat was

Figure 3.7. "Dairy & residence of E. Nason, San Felipe, San Benito Co., Cal." This 1881 sketch shows one of the many dairies in the San Felipe district in the 19th and early 20th century (cows at right). Lovers Lane is seen in foreground. (Elliot and Moore 1881)

still described as the principal crop of the southernmost portion of the valley, fruit had become the most profitable. Harrison (ca. 1888) describes the changing agricultural landscape around Gilroy:

> Farming has been and is the leading industry of this portion of the valley, the principal products being wheat and barley...Most of the country south-east of Gilroy, and notably a portion of it too wet for cultivation is useful to pasture dairy stock...But the profits of the fruit industry have eclipsed all others, and the adaptability of Gilroy soil and climate to this...is causing the rapid planting of vines and trees. Sufficient has already been done in this line to place it beyond an experiment.

Many of the orchards and vineyards detailed in the piece were planted 4-6 years earlier, around 1882-1884. The first orchards in the Pacheco valley area were introduced around 1910 (Cosby and Watson 1927b).

"Five miles from the city [Gilroy] is a tract of land containing 5,500 acres, the property of Messrs. Lion and Buckley of San Jose. This property was bought by these gentlemen a year or so ago, and when the demand for Gilroy land justifies, it will be cut up and put on the market. It is splendid fruit land. Beyond this tract, and on the eastern side of the valley, is a large area of virgin soil, beautiful level valley land, covered with wide-reaching oaks, ably fine vine land, and is the least populous of all the Gilroy section of country. There are 40,000 acres of land here upon which there are less than a dozen residences."

\- HARRISON CA. 1888

The area between Morgan Hill and Gilroy continued to be held by a few large landowners until nearly the turn of the century (1892-3), and thus developed into orchards slightly later than the country around Gilroy, resulting in more documentation of the natural patterns of oak lands in this area (see fig. 6.6). Orchardists took advantage of intermittent stream conditions to plant occasionally on the less frequently flooded stream terraces along Uvas-Carnadero Creek, and at least one enterprising family on Carnadero Creek dried fruit in the sand in the dry river bed: "[w]ater is nicer than sand for scenery, but for fruit-drying the last is better" (Kenderdine 1898).

The extent of orchards in South Valley continued to expand exponentially in the late 19th and early 20th centuries. In 1889, there were 5,381 prune and plum trees in San Benito County; by 1899 there were 143,455 (Cosby and Watson 1927b). While in 1890 orchards covered only 10% of the agricultural land in the Santa Clara Valley (Broek 1932), by 1905 Gilroy was boasted to have "half the prune and apricot trees of America" (Unknown 1904). By the 1930s, south Santa Clara Valley orchards (mostly prunes) covered about 65% of total cropland and "nearly three-quarters" of the irrigable land (Blackie and Wood 1939). The alluvial valley floor between Morgan Hill and Gilroy was "almost solidly planted to deciduous fruits and grapes" (Blackie and Wood 1939; fig. 3.8).

The notable exceptions to this horticultural expansion were the lower Llagas Creek and Soap Lake areas, poorly drained areas which were used for grains and pasture even into the 1940s (Stimson 1944). Wetland soils immediately surrounding and east of Gilroy, and to the east of the Bolsa, remained alfalfa and dairy farms. Poorly drained or unirrigable land in the Bolsa and on the valley periphery remained grazing land.

Irrigation

Little evidence of ditching, either for irrigation or for drainage purposes, existed in South Valley until the 1870s. Drainage ditches seem to have been more prevalent than irrigation ditches in most parts of South Valley, reflecting the early prevalence of dry farming and challenges presented by floods. Since much of the southern part of the study area (including between Old Gilroy to the north and around Fallon Road in Hollister to the south and encompassing nearly the entire width of the valley) was historically an area of artesian flow,

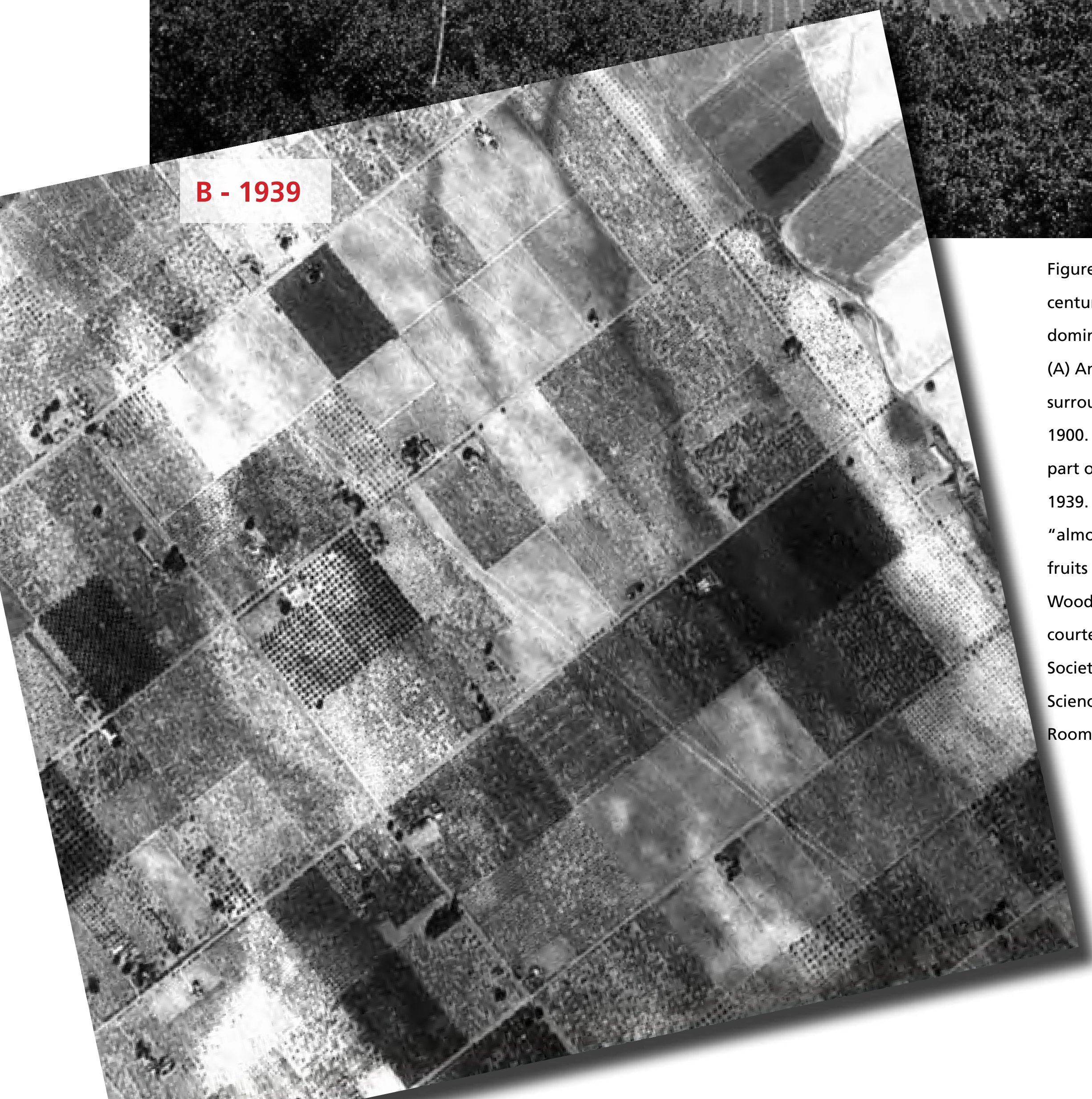


Figure 3.8. By the turn of the 20th century, orchards had begun to dominate South Valley agriculture. (A) An oblique view of Morgan Hill surrounded by orchards in bloom, ca. 1900. (B) An aerial view of a different part of the Morgan Hill region, ca. 1939. The alluvial valley floor is "almost solidly planted to deciduous fruits and grapes" (Blackie and Wood 1939). (A: Unknown ca. 1900a, courtesy of the Morgan Hill Historical Society; B: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz)

there was little need or incentive for stream diversions for irrigation. Further, South Valley creek flows were considered erratic and unreliable, limiting their utility for irrigation (Clark 1924, Burch 1924(?)). The few surface diversions that did exist were mainly used for winter irrigation, supplementing summer use of well water. The predominant form of irrigation in South Valley has always been groundwater, not surface water: Clark (1924) explains that "[a] small area is irrigated by spreading the winter floods of streams, but a considerable part of this area is later irrigated with water pumped from wells, the winter flooding being only supplementary to the summer irrigation. It is perhaps safe to say that from 80 to 90 per cent of the irrigated land in the valley is irrigated with water pumped from wells."

Irrigation ditches and other water supply systems were built earliest in areas without access to artesian water. The city of Gilroy had a dam on Uvas-Carnadero Creek by the early 1870s just south of the Uvas/Watsonville Road intersection. The dam was moved upstream around 1875 to what was to become the Uvas Reservoir damsite over eighty years later. Water from the dam was carried through a flume to a reservoir in the hills west of town, then distributed through pipes to residents of the city (Herrmann 1888b, Herrmann Bros. 1890). Further north, by San Martin, water was "piped from a great spring on the ranch in the hills" (Unknown 1904).

Though early mentions of the use of surface water for irrigation occur in the late 1870s (e.g., San Benito Advance 1877), substantial systems for surface water irrigation appear to not have been built until the 1890s. Even then, they were not prevalent, and were secondary to the use of groundwater. In 1891, a reservoir (out of the study area, near Paicines) and system of canals designed to irrigate the lands around Hollister with San Benito River water were built by the Hollister Irrigation Company, irrigating lands as far north as McCloskey Road and the Buena Vista district of Hollister (Burch 1924(?), McCallum 1974). This development opened the way for much more intensive horticulture in the Hollister area (largely prunes and apricots; Cosby and Watson 1927b). This system was unreliable, however, and farmers still needed additional irrigation water from wells (Burch 1924(?), McCallum 1974). In 1912, Paicines Reservoir was added to the system (Gross 1938). This system remained in use until the connection of the San Felipe Unit to San Luis Reservoir through the San Felipe Project in 1987, which brought Central Valley Project water in over the Pacheco Pass (Harris 1989).

> *"Considerable grain is raised in Santa Clara Valley without irrigation, most of the vineyards are not irrigated, and even many orchards are not irrigated, especially in the Morgan Hill district and in the district around Cupertino and Los Gatos. In 1913 the grain crop was almost a complete failure, owing to the very light rainfall of that year..."*
>
> – CLARK 1924

Drainage

Most of the artesian area supported seasonal or perennial wetlands. Drainage ditching began early in many of these areas, especially in the northern Bolsa and around the mouths of the Uvas-Carnadero and Llagas creeks. Samuel Rea cleared wetland covered with willows and grasses in 1863 at the mouth of the Carnadero (near the current intersection of Bloomfield Avenue and Highway 25), then started a dairy farm on the cleared land. Ditches at the mouth of Llagas Creek were probably constructed sometime in the late 1870s or early 1880s, draining the swamp south of Old Gilroy. Additional drainage for this area was constructed in the 1920s (Cosby and Watson 1927a). Yet remnants of willow groves can be seen into the 1930s (USDA 1939; see fig. 5.16), indicating the difficulty of their complete removal.

Further south, Millers Canal, the most ambitious drainage project of the era, was completed in 1874 "with the view of draining a portion of Soap Lake." It created an outlet for San Felipe Lake by connecting the lake with the Pajaro River (Hollister Advance 1873). In doing so, it opened around 2,800 ha (7,000 ac) of land for farming (Hollister Advance 1874).

Millers Canal

Henry Miller, the infamous land-owner and cattle baron of the San Joaquin Valley, also played a large role in South Valley water politics. He owned about 300,000 ha (750,000 ac) of land in California (Bancroft [1890]1970), including at least 8,000 ha (20,000 ac) in the Santa Clara Valley (acquired beginning with the purchase of 700 ha/1,800 ac of the Las Animas Rancho in 1859; Milliken et al. 1993, Roddy 1995). Along with fellow cattleman Charles Lux, Miller owned land on the Las Animas rancho south of Gilroy, on the Llano de Tequisquita rancho surrounding the northern half of San Felipe Lake, and on the Juristac Rancho. The Bloomfield Ranch area was well-situated for Miller & Lux's operations: a place easily accessible from Pacheco Pass that could serve as a stopping place for cattle on their way from the pair's vast holdings in the San Joaquin Valley to San Francisco markets (see top image, p. 13). The area was ideal for these purposes because of its expansive, naturally wet meadows - Miller described it as "well watered, nice country, nice grass, and a nice place to camp" (Igler 2001). Included on their property was the sequence of seasonal and perennial wetland habitats connecting San Felipe Lake to the more well-defined reach of the Pajaro River.

Interested in transforming their Llano de Tequisquita ranch into viable grazing land, in 1873 Miller & Lux began to build a canal to improve drainage on their Soap Lake property (Hollister Advance 1873). The canal was completed in January 1874, as reported in The Hollister Advance: "Miller & Lux have completed their canal for draining Soap Lake. It is nearly 3 miles in length, and reclaims some 6,000 or 7,000 acres of very fine land. At the bottom it is 14 feet wide, at the top it is 26 feet wide, with a depth ranging from 3 to 7 feet" (Hollister Advance 1874). The canal became the predominant drainage feature of the western Bolsa, conducting water directly from San Felipe Lake to a point downstream on the Pajaro River just north of Bolsa Road, bypassing the shallow, undefined section connecting the Pajaro to the lake. Broek (1932) summarized this system, and its modification: "the Millers Canal which, in place of the shallow winding beds which is the beginning of the Pajaro River, now affords an adequate outlet for the San Felipe Lake."

By the 1940s and '50s, the capacity of Millers Canal to drain the Bolsa had become reduced by vegetation growth, siltation, and deliberate infill to allow crossing of the channel.

"According to local landowners the canal was, up until 15 years ago [1944], adequate during normal years," said the head of the local Soil Conservation Service in 1959. *"At that time the Miller Canal was kept open and had not as yet silted or had produced the terrific vegetation growth that is evident today"* (Hollister Evening Free Lance, July 1959).

Though it was certainly the most prominent, Millers Canal was not the only drainage modification to the Soap Lake landscape. By the early 1900s, another canal is shown connecting Tequisquita Slough with San Felipe Lake east of the wide, shallow channel of Tequisquita Slough itself (figs. 3-9 and 3-10). The canal was built on the Emery Ranch southwest of the lake (what was to become Spreckels Sugar Company land).

The groundwater problem

With a few exceptions (for example, early dry farming on orchards near Morgan Hill; Clark 1924), orcharding on the valley floor was an irrigated enterprise (Cosby and Watson 1927a; fig. 3.11). T.S. Kenderdine, observing the ranch of a friend of his on the Carnadero near Gilroy, remarked that "without irrigation orcharding would be a poor business" (Kenderdine 1898), and Clark (1924) noted that "without

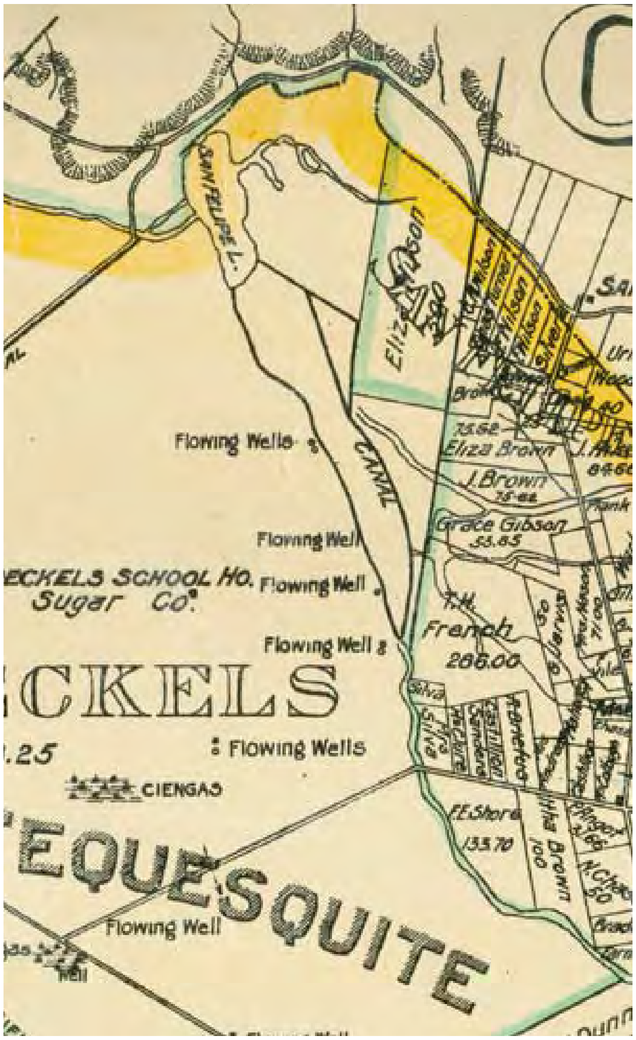


Figure 3.9. This 1907 property map of the San Felipe Lake area shows both Millers Canal (upper left) and another series of straight canals (labeled "canal") to the right of Tequisquita Slough. The canal was built on the Emery Ranch southwest of the lake (what was to become Spreckels Sugar Company land, as it is labeled here). (McCray 1907, courtesy of the Earth Sciences and Map Library, UC Berkeley)

irrigation the valley would of necessity be given over largely to the production of oat and barley hay." Dairying, too, required extensive irrigation. Alfalfa, the predominant feed for dairy cattle, required more than twice the quantity of water as did orchards (Clark 1924). As a result of these water needs, the number of artesian wells ballooned from 1880 to 1900.

The effects of so many wells on the groundwater table was rapidly felt. Exacerbated by a dry spell during 1897-1899, by 1898 pumping was needed to extract water from previously free-flowing wells in the San Felipe district (McCallum 1974). Another dry spell from 1907 to 1910 further worsened the problem as those who relied on stream flow for irrigation turned to an already falling groundwater supply (Tibbetts and Keiffer 1921). By 1910, Wells (ca. 1910) observed that around San Felipe "some of the wells do not always flow, and the use of pumps is general."

The dry spells of 1897-1899 and 1907-1910, coupled with intensive water use by dairies (alfalfa) and orchards, began to make artesian wells a decreasingly reliable water source. By 1910, many wells flowed only during the winter, and most required pumping (Wells ca. 1910). Increased pumping led to even further declines in groundwater levels. From 1916 to 1923, the water table for the Hollister district dropped an average of 2.5 m (8 ft; Burch 1924(?)). Cosby and Watson (1927b) described an even more severe rate of recession of 2-2.5 m (6-8 ft) per year.

By 1936, depth to groundwater had plunged in some places a further 10-12 m (35-40 ft; Gross 1938, McCallum 1974). Broek (1932) wrote that in the artesian zones, "wells had by 1924 ceased to give sufficient discharge for irrigation use, and by now have entirely stopped flowing." The electrification of rural areas, coupled with the development of powerful turbine wells in the 1930s, further contributed to falling groundwater levels (Prince et al. 1995, Yates pers. comm.).

FLOOD CONTROL AND URBAN EXPANSION: MODERN ERA (1930-PRESENT)

Water storage

As groundwater resources diminished, interest increased in surface storage as a way to both recharge groundwater and make surface flows a more useful, reliable form of irrigation (Gross 1938). The Hollister Irrigation District

Figure 3.10. "Irrigation canal on Emery Ranch, Soap Lake, looking downstream," ca. 1900. This is likely the same canal as depicted in Figure 3.9. Interestingly, the image is labeled "Irrigation Canal," suggesting that it was not just used for drainage. (Unknown ca. 1900b, courtesy of the San Benito County Historical Society)

Figure 3.11. "Irrigating an Orchard near Hollister, California," ca. 1910. (Unknown ca. 1910a, courtesy of the San Benito County Historical Society)

was formed in 1923 to attempt to replenish groundwater supplies through percolation and dam construction (McCallum 1974). In 1931 the Pacheco Pass Water District (including land on both sides of the county line) split off from the Hollister Irrigation District, and by 1939 had completed construction of Pacheco Reservoir (6,150 ac-ft; Stimson 1944). In 1953, the San Benito County Water Conservation and Flood Control District was created in lieu of the Hollister Irrigation District (McCallum 1974). Hernandez Reservoir on the San Benito River was completed in 1962 (18,700 ac-ft; Creegan and D'Angelo-McCandless 1977). On the Santa Clara side of the county line, the South Santa Clara Valley Water District completed Chesbro Reservoir (8,090 ac-ft) in 1955 and Uvas Reservoir (9,950 ac-ft) in 1957. Central Valley Project water was imported into Santa Clara and San Benito counties via Pacheco Pass from San Luis Reservoir beginning in 1987 (McArthur and Wessling 2005), and groundwater levels began to rise in the Soap Lake area during wet years in the mid-1990s (Yates pers. comm.).

"Local interests have constructed small reservoirs for irrigation and provided irrigation wells and canals. In normal years these are inadequate to meet irrigation needs after the month of March."

– STIMSON 1944

Flood control

While significant local efforts to drain the perennial wetlands of the lowlands began in the second half of the 19th century, major efforts to reduce flooding from South Valley stream courses came relatively late. Pacheco, Chesbro, and Llagas dams, constructed in the mid-20th century for groundwater recharge, also provided some associated flood protection benefits. However, local streams continued to flood in the 1950s and 1960s, with particularly damaging overflows in 1955. The most extensive flood protection efforts took place on Llagas Creek beginning in the early 1970s, when Caltrans excavated over 16 km (10 mi) of the channel to provide fill material for the construction of Highway 101 (USDA 1982). The project was halted in 1974 to evaluate environmental impacts following the passage of the National Environmental Policy Act (USDA 1982). Since then, revised designs are being sequentially implemented (SCVWD 2007b). Levee construction and main channel excavation have been common on both the Llagas and Uvas-Carnadero, allowing development of the outer portions of the former channel area.

> *Gilroy Correspondence – Some of the roads have got badly washed out and some minor bridges washed away. Cole's bridge stood the water. Cole, on the following morning was seen on top of it singing, this bridge will brave a thousand years, the freshets and trustees.*
>
> – SAN BENITO ADVANCE, NOVEMBER 27, 1875

Modern agriculture

By the 1930s, South Valley agriculture began to transition into seed and row crops, often on topographically lower, heavier soils previously covered by seasonal or perennial wetlands (MacGraw 1961). By the end of the decade, orchards still dominated the area (comprising 64% of the agricultural land), but row crops (along with alfalfa and sugar beets) were a significant land use, comprising 25% of the agricultural land in South Valley (Blackie and Wood 1939).

> *"The vegetative cover pattern, like precipitation, varies with elevation. The general pattern is row crop farming on the lowest valley lands, orchard within the main valley area, small grain and pasture on the higher valley lands, range land in the foothills, and dense brush and some timber in the higher hills."*
>
> – LOMA PRIETA SOIL CONSERVATION DISTRICT ET AL. 1967

Land use varied with soil type and topography. Orchards were differentially planted on well-drained alluvial soils in the Pacheco valley and north of Gilroy, while vegetable crops dominated low-lying areas to the south and east of Gilroy. Stimson (1944) noted that "Uvas, Carnadero, and Llagas...cause flooding of areas planted to orchards and vineyards in the upper reaches and to row crops in the lower reaches."

By 1980, orchards had ceased to define South Valley agriculture: "Farmland is devoted primarily to row crops with small areas of orchards" (USDA 1982). This trend has largely continued to the present day. Orchards are almost completely absent, while row crops such as lettuce, bell peppers, spinach, and mushrooms predominate (Santa Clara County Department of Agriculture 2005). Nursery crops are also a lucrative crop in the region.

Urban expansion

Gilroy has been the prominent American town of the study area since its incorporation in 1870. The town was originally located to the east, in what is now called "Old Gilroy," but moved to the present-day location with the coming of the railroad in 1869. Morgan Hill developed much later, and incorporated in 1906.

In the 1880 and 1890 censuses, Gilroy was the third largest town in Santa Clara County (with a population of about 1,600-1,700; California State Department of Finance 2000), eclipsed in size only by San José and Santa Clara. (Morgan Hill did not yet exist.) By the 1900 census, Gilroy had dropped to 4th place; by 1940, to 6th place (population 3,615). By the end of the northern Santa Clara County population boom of the 1950s and 1960s, Gilroy was only the 13th largest city in the county.

In the 1980s and 1990s, population expansion in South Valley began to outpace growth in northern Santa Clara Valley cities. Gilroy tripled in size between 1970 and 2000 (to a population of 41,464), sending it back up in the 2000 census population rankings as the 8th largest Santa Clara County city. Morgan Hill, however, grew to six times its population (population 33,556), to 10th place, and now approaches Gilroy in size. While both cities continue to expand, these two major population centers of South Valley are both still small in comparison to other Santa Clara Valley cities.

4 STREAM AND RIPARIAN HABITATS

Above. Uvas-Carnadero Creek at the Hecker Pass Road crossing; images from 1939, 2005, 1884, and 1876 (clockwise from upper left).

STREAM AND RIPARIAN HABITATS

Substantial historical resources are available to document the historical extent and character of an array of riverine, wetland, and dry land habitats in south Santa Clara Valley. Many of these habitats are of contemporary restoration and conservation interest. In Chapters 4 through 6, we describe specific methods and findings for each habitat type and discuss some of the potential implications for environmental restoration and conservation. We focus first on stream and riparian habitats (Chapter 4), then wetland habitats (Chapter 5), and lastly, dry land habitats such as oak woodland and savanna (Chapter 6).

Despite occupying a relatively small area compared to other habitats, streams and their riparian habitats provide an important array of ecological and hydrogeomorphic services (NRC 2002). California streams can provide habitat for an array of species of concern, including the western pond turtle *(Clemmys marmorata)*, red legged frog *(Rana aurora)*, and steelhead trout *(Oncorhynchus mykiss)*, of particular conservation interest in the Santa Clara Valley (SCBWMI 2003). Specific combinations of riparian vegetation and in-stream aquatic habitat are vital for communities of native fish, songbirds, waterfowl, and other species. Changes in channel form, including width and depth, plan form alignment, and network connectivity, can greatly alter species support functions. Such changes can also directly affect the potential for bank erosion, fine sediment storage or release, and flooding (Pearce and Grossinger 2004). Previous research in the neighboring Coyote Creek watershed identified significant and largely unrecognized changes in stream characteristics during historical times (Grossinger et al. 2007a), while at least one restoration project in the area has failed because of the lack of information about historical stream function (Kondolf 2006).

To address these questions, we evaluated several different attributes of local stream systems. To document changes in channel position and alignment, drainage density (including channel extension), and connectivity, we compiled a detailed map of pre-modification drainage patterns. To assess potential changes in riparian cover, we measured the proportion of savanna, woodland, and forest along mainstem channels. Given the significance of the sycamore alluvial woodland remnant on Pacheco Creek (Keeler-Wolf et al. 1996, Jones and Stokes 2006), we endeavored to document the historical distribution and extent of this habitat in the study area. Since our initial investigations suggested substantial loss of broad braided channel and wetland reaches, we also developed an approach to quantify historical changes in channel width by reach. To provide perspective on questions of dry season base flow prior to surface water management and groundwater withdrawal, we assembled available evidence describing summer flow conditions and persistent pools on local streams. Finally, we attempted to assemble historical data describing pre-modification channel cross-sectional geometry (although relatively little comprehensive information was found in this regard).

METHODS

We developed a map of the historical drainage network based upon the diverse array of available historical data sources. Valley floor stream channels were classified as mainstem channels (of the Llagas, Uvas-Carnadero, Pacheco, or Pajaro), side channels (also known as secondary, overflow, or high flow channels), or creeks. Low gradient, shallow channels within broad wetland areas were classified as floodplain sloughs (Collins et al.

2003). All features were coded with regard to source and certainty level (see table 2.1).

To map historical stream alignment, we started with the contemporary hydrography GIS layers of the Santa Clara Valley Water District (SCVWD, 2007a) and, for the San Benito County portion of the study area, the National Hydrographic Data Set (USGS 2005). We only mapped historical channels when the historical stream course clearly differed from the current alignment. Where historical position was within 15 m (50 ft) of the contemporary position, we maintained the contemporary line feature. This approach avoids the generation of "crisscrossing" non-coincident lines representing the same feature, which could potentially be mistaken for channel migration.

We compared early aerial imagery (USDA 1939) to contemporary imagery (USDA 2005) to identify modern, post-World War II changes to the drainage network. To evaluate earlier change, we used over 35 19th-century professional surveys (e.g., McDonald 1852(?)a,b,c; Healy 1858b, Herrmann Bros. 1884) that were sufficiently detailed and accurate to confirm the 1939 plan form and/or identify former meanders. General Land Office (GLO) surveys (1850s-1870s) crossed stream channels at many locations in the study area, providing additional information about channel position. The mid 19th-century GLO and land grant information was critical for interpreting pre-modification drainage patterns in large wetland areas, most of which were extensively altered before the 1930s. To identify the locations where defined, single thread channels terminated and spread into distributaries or overland flow, we used a number of maps and written accounts that explicitly defined the transition. Where such information was not readily available, we inferred this transition point based upon patterns observed on the more well-documented systems. Sinuous channels with riparian trees that abruptly shift to unvegetated straight-line channels in early aerial photography can be good indicators (Grossinger et al. 2006); these features were coded with lower level certainty.

We then evaluated the origin of the contemporary valley floor drainage network, classifying contemporary stream channels in one of four categories: channels that follow their historical alignment, new straightened or realigned channels that replaced historical alignments, new channels that connect formerly discontinuous segments of the drainage network, or completely new drainages constructed in formerly undrained areas of the valley floor. We did not correct the contemporary stream network's layers. As a result, channels and ditches that may have been left out of the SCVWD or NHD layers were excluded from this analysis of the contemporary drainage network. Since the contemporary stream mapping (USGS 2005, SCVWD 2007a) is generally less detailed than our historical mapping, we were unable to perform a direct quantitative comparison of channel density.

To assess large-scale shifts in riparian plant community structure, we classified mainstem stream reaches as forested (canopy cover greater than 60%), woodland (25-60% cover), or savanna (less than 25%). These standards follow federal vegetation definitions (FGDC 1997). We also recognized two additional distinct reach types. Multi-channeled stream reaches dominated by emergent freshwater marsh vegetation and/or willow swamps were classified as "wetland" reaches. Slough or swale reaches with no tree cover in an alkali meadow context were classified as "alkali slough" reaches, particularly referring to the Pajaro River drainage upstream of Llagas Creek. Percent cover was estimated visually based upon measured standards, while wetland reaches were defined from the historical wetland mapping component of the project (see Chapter 5). We focused on mainstem reaches, where because of the effects of dam construction and flood protection, shifts may be most pronounced, but similar assessment could be carried out on tributaries. We classified reaches to a minimum length of 250 m (800 ft). This approach was also applied to modern mainstem reaches to allow comparison. These measurements provide an efficient estimate of stream kilometers (or miles) with differing function; area measurements could also be developed.

Preliminary observation suggested that on many reaches the width of naturally braided channel has been constricted due to the construction of streamside levees. To estimate the extent of change in the width of active channel/riparian corridor, we classified mainstem reaches past and present with regard to their width, using recognizable indicators such as riparian forest and scoured channel surfaces (Kondolf et al. 2007).

To evaluate large-scale patterns in riparian tree community composition, we assembled all available species-specific riparian tree information from the historical record, including textual descriptions and early landscape photographs of streams. We found several dozen riparian trees used as bearing trees in 19th-century GLO or county surveys, and over 20 19th- or late 18th - century quotes describing riparian community composition. These data were compared to early maps and aerial photography, which cover larger areas.

Early aerial photography showing occasional large trees occupying bars and terraces in broad, mostly unvegetated alluvial channels provides another line of evidence for riparian habitat. We calibrated this locally common visual pattern with the historical tree data and contemporary field observation. The large remnant sycamore alluvial woodland areas along Pacheco Creek, and remnant trees on other creeks, were particularly useful in this regard.

To assess historical dry season flow and aquatic habitat, we compiled as many descriptions of streams during the dry season (May-November) as possible. To ensure that interpretation was not skewed by extreme wet or dry periods, we collected information from many different decades, and compared each of the data to the climatic record (using San José or San Francisco as a proxy for general inter-annual patterns for years before Gilroy data are available; see Appendix). We also geo-located all references that were well-defined spatially so that potential reach- or watershed-scale patterns could be identified.

RESULTS

South Valley streams exhibited a high degree of heterogeneity before Euro-American modification, including variations in channel morphology, the extent of connectivity, riparian habitat, and summer flow characteristics. Streams have also been modified in a number of discrete ways.

While detailed information about fishing locations and species on local streams is limited, the Gilroy area – which historically referred to the general southern part of Santa Clara County – was well-recognized for its fishing value:

> *"Salmon weighing as much as 12 pounds have been recently caught in the streams near Gilroy. They evidently came up from saltwater."*
>
> – THE PACIFIC COAST, FEBRUARY 19, 1881

> *"The water outlets of Gilroy township... [afford] plenty of sport in the trout and salmon seasons..."*
>
> – MUNRO-FRASER 1881

Changes in the drainage network

At the most fundamental scale, the extent and position of the channels making up the South Valley drainage network has been substantially modified (figs. 4.1 and 4.2). Of the 392 km (250 mi) of channel presently draining the valley, 42% (165 km/100 mi) represents channels artificially constructed following new alignments. Conversely, slightly more than half (53%) of the contemporary drainage network follows historical channel alignments. About 5% (18 km/11 mi) of the existing drainage network consists of channels which have apparently migrated naturally, mostly within a larger braided channel system.

It is important to note that a substantial portion of the channels that still follow their historical alignment are nevertheless heavily modified. For example, Llagas Creek downstream of Highway 101 is an engineered channel that largely follows the historical alignment. Thus the proportion of *non-engineered* channel is actually substantially less than half the valley drainage network.

New channels constructed alongside roads, property boundaries, and other alignments represent almost half of the valley's present-day drainage network.

Of the 165 km (100 mi) of newly constructed drainage, 64 km (40 mi; 39%) is the result of straightening or rerouting (fig. 4.3). The remaining 101 km (60 mi; 61%) were created to drain seasonally flooded lowland areas, rather than to straighten or reroute existing channels. Of that total, 63 km (40 mi) of channel drains areas that naturally had little or no surface drainage and 38 km (23 mi) connects formerly discontinuous creeks to the major streams (Llagas, Uvas-Carnadero, Pacheco creeks and the Pajaro River) or their tributaries.

In addition to physical alterations , some streams have experienced dramatic changes in nomenclature. Carnadero Creek, which once extended all the way to the Bodfish Creek confluence, now is considered to end at Highway 101, thus losing more than half its length to the Uvas (e.g., Herrmann Bros. 1884, 1890; USGS [1915]1917; see fig. 4.26b). To simplify matters, the system is now called Uvas-Carnadero Creek.

Where not modified, many stream alignments have been quite stable over the past 150 years, even braided channels. Where detailed historical maps are available, they

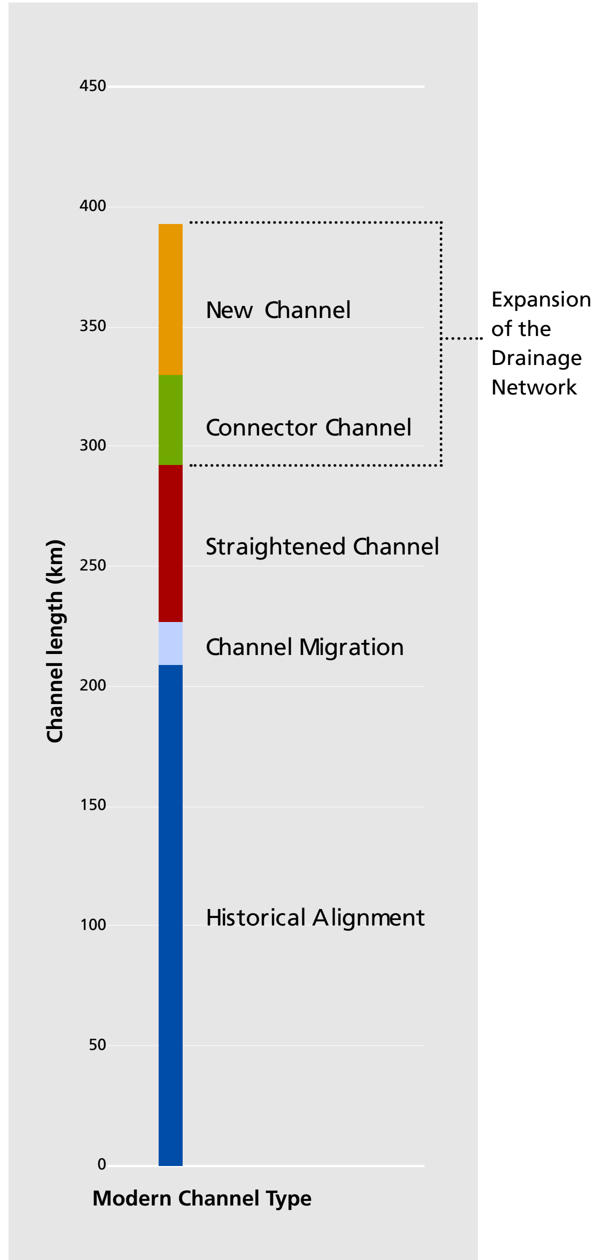


Figure 4.1. This figure describes the channels of the contemporary south Santa Clara Valley drainage network. It includes channels that follow their historical alignment and a small amount of channels that have naturally migrated. It also includes channels that have been straightened, channels dug to connect formerly discontinuous channels, and completely new channels. As a result, the drainage network has been substantially expanded. This same information is presented in map form in fig. 4.2.

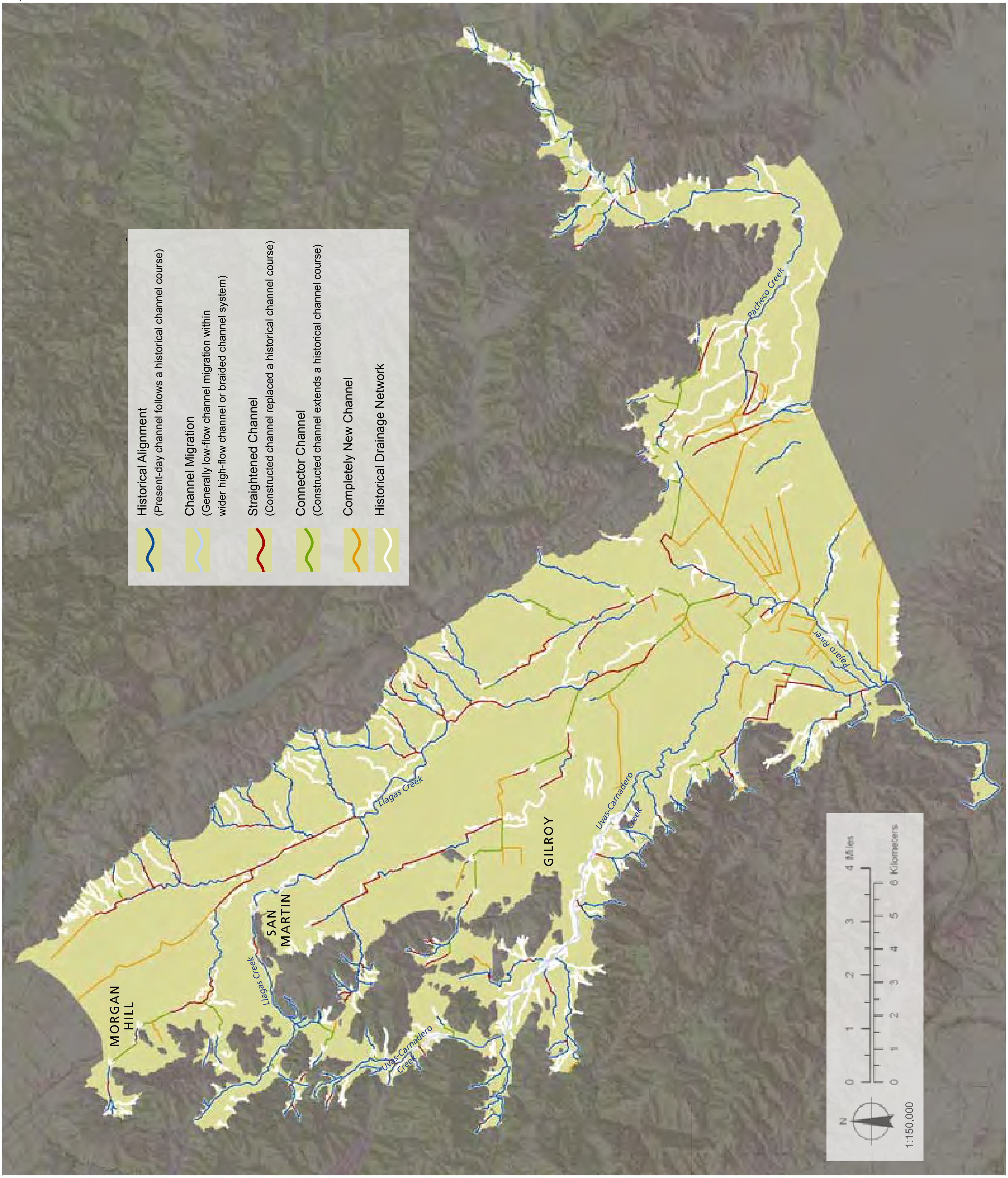


Figure 4.2. Map of the contemporary drainage network, with channels coded with regard to their origin. The historical drainage network is shown in white.

Figure 4.3. Former channel meanders of Llagas Creek. Over 60 km (40 mi) of historical streams (A) have been straightened or rerouted (B). Excavation of Llagas Creek in the early 1970s for gravel to construct Highway 101 and flood benefits produced these isolated oxbows along the current flood control channel (B; USDA 1982). (A: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B: USDA 2005, courtesy of NAIP)

generally match closely (fig. 4.4). Within braided channels, however, the position of mainstem and side channels has been highly dynamic (e.g., figs. 4.20, 4.25, and 4.30).

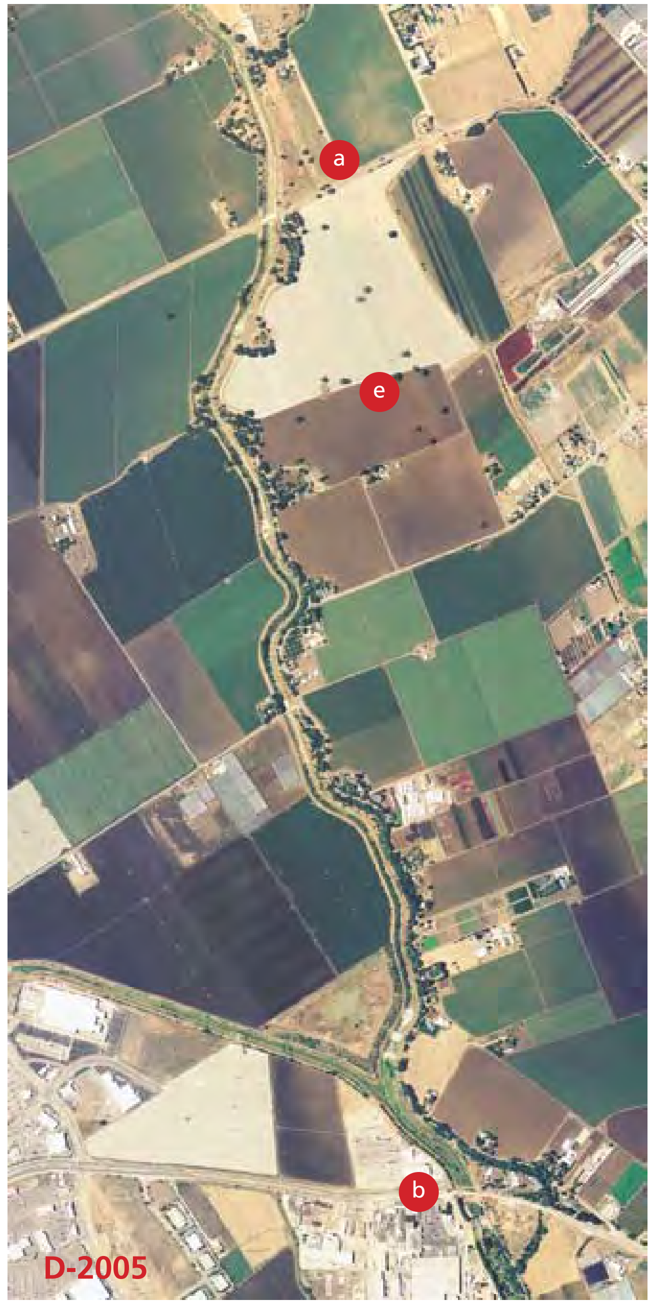
Discontinuous creeks and distributaries

The South Valley drainage network was more diffuse and discontinuous prior to 19th- and 20th-century modifications. In comparison to the present-day drainage network, areas without well-defined channels, or with multiple channels within a wetland context, were common. These hydrologic features are well-documented in the historical record.

The three major tributaries to the upper Pajaro River – Uvas-Carnadero, Llagas, and Pacheco creeks – each branched into smaller distributary channels prior to channelization. These transition points between a well-defined, single thread channel and multiple channels and/or wetlands were each documented by multiple sources. The point of "spreading" was considered to be well-defined and stable enough to serve as part of the county line on lower Pacheco Creek and as a property boundary on lower Carnadero Creek. The latter feature resulted in the unusual shape of Samuel Rea's property (fig. 4.5). Rea was later credited with having "opened a channel for Carnadero Creek" (Shortridge [1896]1986). He likely deepened one of the existing floodplain sloughs shown by Herrmann (ca. 1870; fig. 4.5). Healy located the county line "near where one of the many channels or mouths of the San Felipe Creek [Pacheco Creek] spreads out into the lake" (Healy 1868). Several maps also show this pattern (see fig. 7.29).

Similarly, lower Llagas Creek "finds a low, flat country, and spreading out over many hundred acres, forms a tule swamp" (Harrison ca. 1888). Despite ditching, the lower reaches of Llagas Creek remained shallow into at least the 1950s (fig. 4.6): "in this lower section [the last 5.5 km/3.5 miles of Llagas Creek] the channel is not well defined, and the stream overflows quite regularly during flood periods" (Blackie and Wood 1939). Local residents recollect that "the Llagas channel used to disappear below the Pacheco Pass

Figure 4.4. Llagas Creek between Leavesley Road (a) and Pacheco Pass Road (b). Maps of Llagas Creek by McDonald (A-1852) and Herrmann (B-1875) match later aerial photography meander for meander (C-1939 and D-2005). Former meanders on Llagas Creek can be seen upstream and downstream of Leavesley Road. The 1875 map also shows former distributaries of Llagas Creek spreading into wetlands (c) and several mid-channel bars (d). Oak savanna in the valley around the creek is suggested by the scattered trees in 1852 map; some remnant trees (e) are visible in 1939 (C)



and 2005 (D). The wetlands adjacent to the creek (c) suggest a relatively high water table in this area, as does the large willow grove just to the south of Pacheco Pass Road (b). (A: McDonald 1852(?)a, courtesy of The Bancroft Library, UC Berkeley; B: Herrmann 1875b, courtesy of the Office of the Santa Clara County Surveyor; C: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; D: USDA 2005, courtesy of NAIP)

Figure 4.5. (A) The elegant Thompson and West atlases were commercial products produced by a traveling team. Created primarily by compiling existing information, they can show substantial detail but can also be inaccurate or imprecise in their depictions (Askevold 2005). The northern boundary of the Rea property (a) was defined by "the point where the 'arroyo del Carneadero' begins to branch into several channels" (Lewis 1851), leading to an unusual plat shape. (B) This county survey shows Carnadero Creek and Tar Creek spreading into multiple channels as they enter the Carnadero willow grove. (A: Thompson and West 1876, courtesy of the David Rumsey Map Collection; B: Herrmann ca. 1870, courtesy of the Office of the Santa Clara County Surveyor)

Figure 4.6. "Llagas Creek channel looking south from Bloomfield Road bridge," January 1955. Despite decades of ditching by this time, the channel remains shallow and narrow. The present-day flood channel can be seen in figs. 4.16 and 5.16. (Soil Conservation Service 1955, courtesy of the Gilroy Museum)

bridge." Farmers would create ditches to drain the water, but the channel was not made larger until after World War II (Sturla pers. comm., Sanchez pers. comm.).

> *". . . the many channels or mouths of the San Felipe [Pacheco] Creek."*
>
> – HEALY 1868

Smaller creeks descending from the hills often dissipated across their alluvial fans, dividing into multiple distributary channels, dropping their sediment, and soaking into the ground. This phenomenon was shown locally by early maps such as Herrmann Bros. (1890; fig. 4.7) and is well-documented within Santa Clara Valley (e.g., Goals Project 1999, Brown 2005, Sowers and Thompson 2005, Grossinger et al. 2006).

As a result, large areas of the valley were not naturally drained through fluvial channels. Discontinuous streams sank into their alluvial fans or spread into shallow floodplain sloughs within wetlands. This less efficient drainage system attenuated flood peaks through broad shallow storage areas and maximized the retention of water for groundwater recharge and valley wetlands.

Floodplain sloughs

A number of drainage features had characteristics distinct enough from common arroyos, creeks, or rivers to be considered sloughs, or even swales. These features were part of a more diffuse, shallow drainage system closely connected to the surrounding floodplain.

> *"... willow thickets indicate several shallow sloughs which drain into the San Felipe Lake, the principal one being Tequisquita Slough."*
>
> – BROEK 1932

Historical examples suggest that the commonly used term "slough" applies to very low gradient, slow-moving channels subject to flooding. They often have relatively high width/depth ratios. Sloughs range in size and can carry water year-round or be dry much of the year. The term "bayou," used occasionally by GLO surveyors in Santa Clara Valley, means "small, slow-moving stream" and also conveys this character. Historically, these features were recognized as distinct from deeper arroyos or creeks; remnants of this terminology include Miller Slough and Tequisquita Slough. Floodplain sloughs were also common features of the historically diffuse drainage systems of the eastern and northwest U.S. (e.g., Collins et al. 2003, Walter and Merritts 2008).

Sloughs were found almost exclusively within wetland areas, and were common in low gradient areas such as the Bolsa. Some details about these features are available. Surveyor Sherman Day (1854) crossed the Bolsa between June 9 and 22, 1854. For the most part, he describes dry sloughs with widths ranging from 2-5m/10-25 links wide [7-17 ft]. Terrell (1858) similarly reports a slough 25 links

Figure 4.7. Historical maps commonly use the "crowfoot" symbol to show the point at which streams lose definition. (A: Herrmann Bros.1890, courtesy of Branner Earth Sciences Library and Map Collections, Stanford University; B: Herrmann ca. 1873b, courtesy of the Office of the Santa Clara County Surveyor)

wide. Some of these dry sloughs are also referred to as "salty" or "alkaline," indicating that they are seasonally evaporative. These features can be considered seasonally ponding components of the alkali meadow landscape. While some of these features are evident in early aerial photography, generally only remnants of the larger sloughs are visible (see fig. 5.7).

However, Day (1854) also describes a "marshy slough, with water nearly level with the plain." This slough, a tributary to Tequisquita Slough west of San Felipe Road, was likely perennial, receiving groundwater discharge. Tequisquita Slough 60 m (200 ft) east of San Felipe Road also had midsummer water in 1854, described as a "large bayou or sluggish creek" over 100 feet wide (Day 1854). Tequisquita Slough connects with Arroyo de las Víboras about a mile upstream from here; Day's description conveys that transition. Accordingly, Broek (1932) describes the hydrological landcape of the eastern Bolsa: "[w]illow thickets indicate several shallow sloughs which drain into the San Felipe Lake, the principal one being Tequisquita Slough." Tequisquita Slough was the most prominent floodplain slough in the Bolsa and maintained a well-defined channel (consistent enough to have been used as the grant boundary between Ranchos Bolsa de San Felipe and Ausaymas y San Felipe) across much of the plain. Close to San Felipe Lake, however (where the grant line boundary departs from the channel), Tequisquita Slough seems to have spread into a more shallow, wide, poorly defined slough (fig. 4.8).

A set of 1949 cross-sections and photographs of Tequisquita Slough at Shore Road provide an unusually detailed illustration of the comparative geometry of a large floodplain slough and a neighboring, even more diffuse drainage. The cross-section (San Benito County Public Works 1949) shows the slough, here called "Tequisquita Creek", and slightly to the west, a more poorly defined, irregular channel labeled "Tequisquita Overflow."

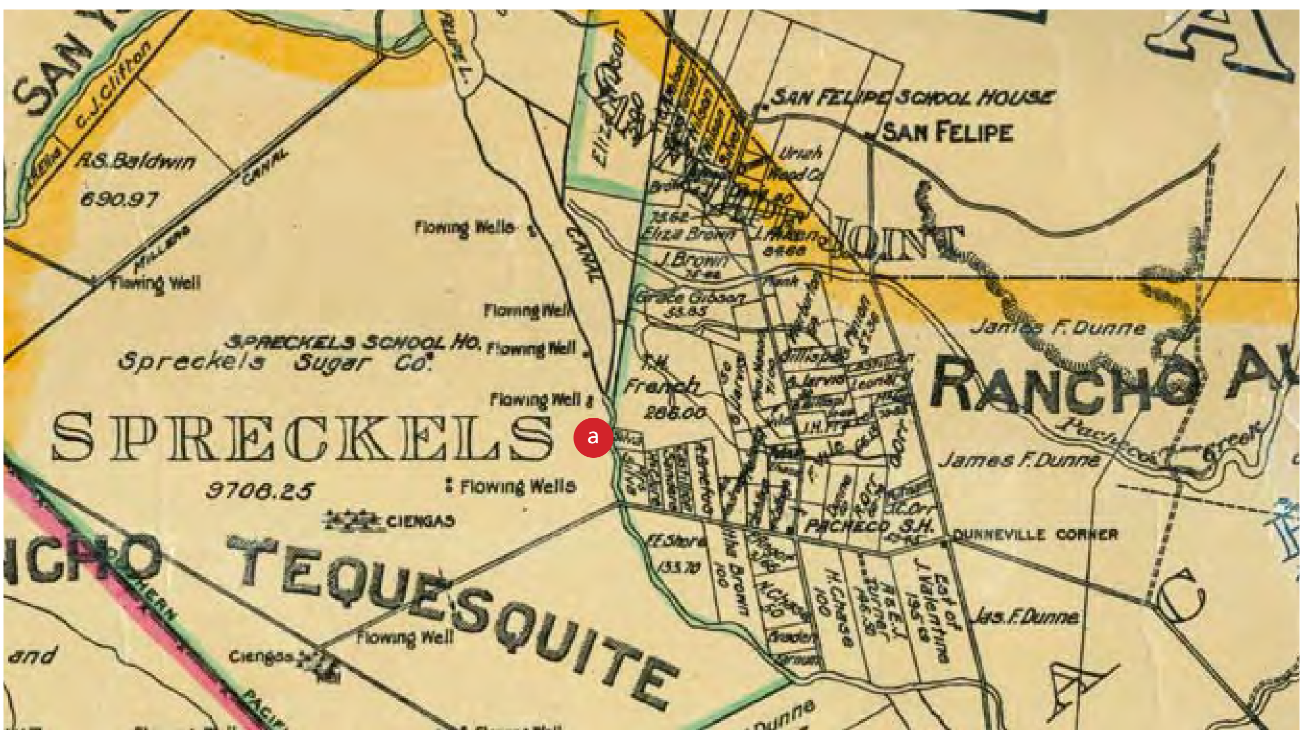


Figure 4.8. At the point where the grant boundary between ranchos Bolsa de San Felipe and Ausaymas y San Felipe leaves Tequisquita Slough, the slough is shown on this 1907 map as changing from a more well-defined channel (shown with double lines) to a less well-defined one (shown as a single line). A canal branching off from the same point (Emery Canal, see figs. 3.9 and 3.10) also leads into San Felipe Lake, presumably to encourage increased drainage. The 1949 photos of the slough in figs. 4.9 and 4.10 are from Shore Road (a). (McCray 1907; courtesy of the Earth Sciences and Map Library, UC Berkeley)

The cross-section shows the original channel dimensions, along with the narrower constructed dimensions. In place of the seven-foot deep constructed Tequisquita "Creek" channel, the historical slough was eleven feet wide and to 1 -4 ft deep. Where the constructed overflow channel is shown on the cross-section, the slough was about 15 ft wide and to 1-2 ft deep.

Corresponding photographs taken of the Shore Road crossing confirm this interpretation. The image of Tequisquita Slough (fig. 4.9) shows a wide channel with a flat bottom and gently sloping sides. The channel was dry at this time (February 1949), likely because of groundwater decline prior to the arrival of imported water supplies (see Chapter 3). The Tequisquita Slough overflow (fig. 4.10) is even more wide and shallow, so much so that the photographer had to take two pictures to cover its entire extent. The feature could probably be considered a swale.

These images correspond to Broek's 1932 description of broad, formerly perennial sloughs:

> In the east [of the Bolsa]...several wide, shallow sloughs carry the winter flow from the Mount Diablo Range and are tributary to the San Felipe Lake... Formerly, when less water was used for irrigation in the orchards and dairies encircling the Bolsa,

Figure 4.9. Rare photographs of a relatively unmodified, broad and shallow floodplain slough: Tequisquita Slough at Shore Road, February 1949. (Unknown 1949a, courtesy of San Benito County Public Works)

Figure 4.10. "Trestle, Shore Rd. Tequisquita slough overflow, before widening. Upstream looking north." The mosaicked 1949 images of the "overflow" channel or swale show the patches of vegetation associated with the microtopography of a shallow drainage: the darker, slightly lower and wetter patches, and the lighter, slightly higher and drier patches. (Unknown 1949b, courtesy of San Benito County Public Works)

> the groundwater table was so high that there were flowing wells in the alkali flat and also sloughs containing water the entire year. Now only the lake and the water courses in its vicinity have perennial water. (Broek 1932)

The connection between San Felipe Lake and the Pajaro River was also a series of sloughs and swales. Similar shallow drainage swales in the lowlands east of Morgan Hill can be identified in early aerial photography and 1970s-era cross-sections. These features, and floodplain sloughs in the Pajaro River riparian corridor, are discussed in Chapter 7.

Riparian corridor width

South Valley streams often had relatively wide active channels supporting a broad, but open, riparian corridor. These corridors along major South Valley streams have, on the whole, narrowed during historical times, reducing the lateral extent of riparian vegetation and active channel surfaces subject to regular scouring and/or flooding (fig. 4.11, 4.12, and 4.13). Prior to channel encroachment, 70% of the mainstem valley floor stream length (Uvas-Carnadero, Llagas, Pacheco, and Pajaro creeks) had an active channel/riparian corridor wider than 60 m (200 ft). Presently, more than 70% of these corridors are narrower than 60 m. There has been a general decrease in the prevalence of broad stream reaches (60-480 m/200-1,600 ft), while narrow stream reaches (<60 m) have increased over 300%.

Some of these changes occurred prior to 1900, as farmers reclaimed some of the higher stream benches and terraces for agriculture (fig. 4.14). These areas can be seen in transition on early maps, where they are labeled with phrases such as "Creek Field" or "Bottom Field" (Herrmann 1875(?), Herrmann Bros. 1884). Agricultural reclamation continued in the 20th century, with these areas visible in early aerial photography as orchards on former stream surfaces (fig. 4.14). Most of the riparian corridor narrowing, however, has occurred since 1970 as a result of more recent flood protection projects. Flood protection efforts have consistently reduced the extent of broad, braided multithread channel morphology by excavating the main channel and constructing levees that separate the channel from adjacent bars and terraces (e.g., USDA 1982; figs. 4.14 and 4.15).

At the watershed scale, this shift is most dramatic along the Llagas, where essentially no medium or broad reaches (>60 m/200 ft) remain (fig. 4.11C). Some broad reaches remain along Uvas-Carnadero and Pacheco creeks (fig. 4.11B and 4.11D). The upper Pajaro River has experienced some decline in riparian width (fig. 4.11E), particularly between the Llagas and Carnadero confluences.

Riparian corridor architecture: forest, woodland, savanna, and wetland reaches

Stream and riparian habitats differed dramatically among different South Valley stream reaches, but within a recognizable regional pattern. This variation can be generally described as differences in the height and spacing of streamside vegetation – the riparian corridor architecture (Kondolf et al. 2007). To evaluate these changes along mainstem reaches of the major South Valley streams, we classified reaches as one of several types (minimum length 250 m/820 ft). Reaches were classified as forested (greater than 60% tree canopy cover), woodland (25-60% tree cover), savanna/unvegetated (less than 25% tree cover), freshwater depressional wetland (multiple sloughs through a broad freshwater wetland or swamp greater than 480 m/1600 ft wide), or alkali depressional wetland (unvegetated sloughs through an alkali meadow).

Within the region, mainstem riparian habitat was almost evenly split between densely wooded forest, moderately wooded woodland, and sparsely wooded savanna channel (figs. 4.16A, 4.12, and 4.13). In fact, there was between 25 and 30 km (15-19 mi) of each of these three classes. Historically, there was also a smaller but substantial length of wetland reaches: a total of 18 km

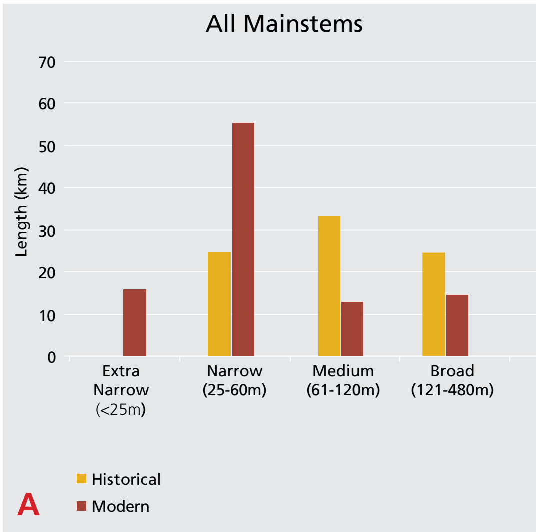
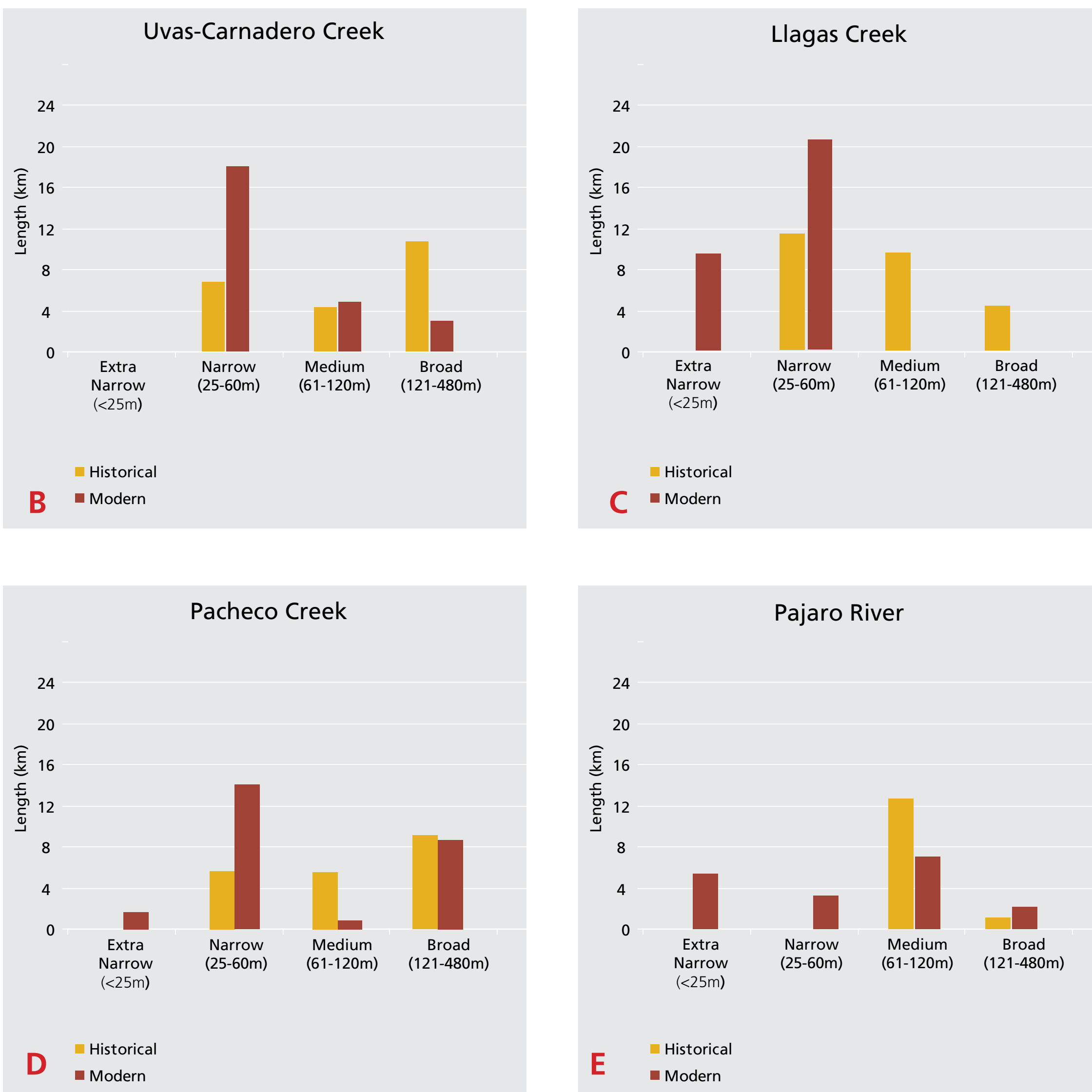


Figure 4.11. Total length of different width classes, past and present, on the Uvas-Carnadero, Llagas, Pacheco creeks and Pajaro River. Measurements are limited to the alluvial, valley floor mainstem reaches.



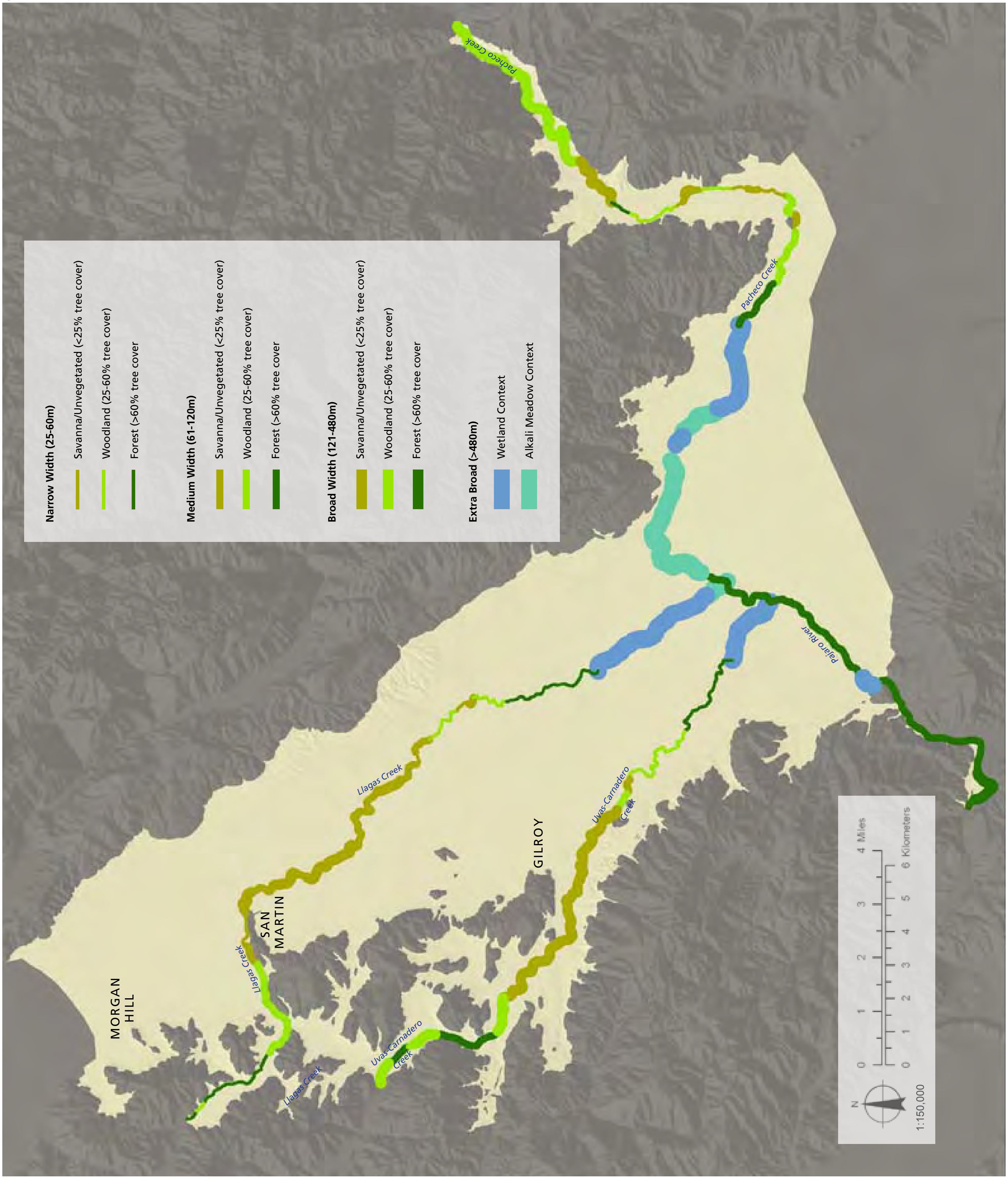


Figure 4.12. Historical riparian corridor width and architecture along major south Santa Clara Valley drainages. Width and riparian architecture/type classes are discussed in the text. Reaches without a single defined channel are described as either surrounded by wetlands or alkali meadows.

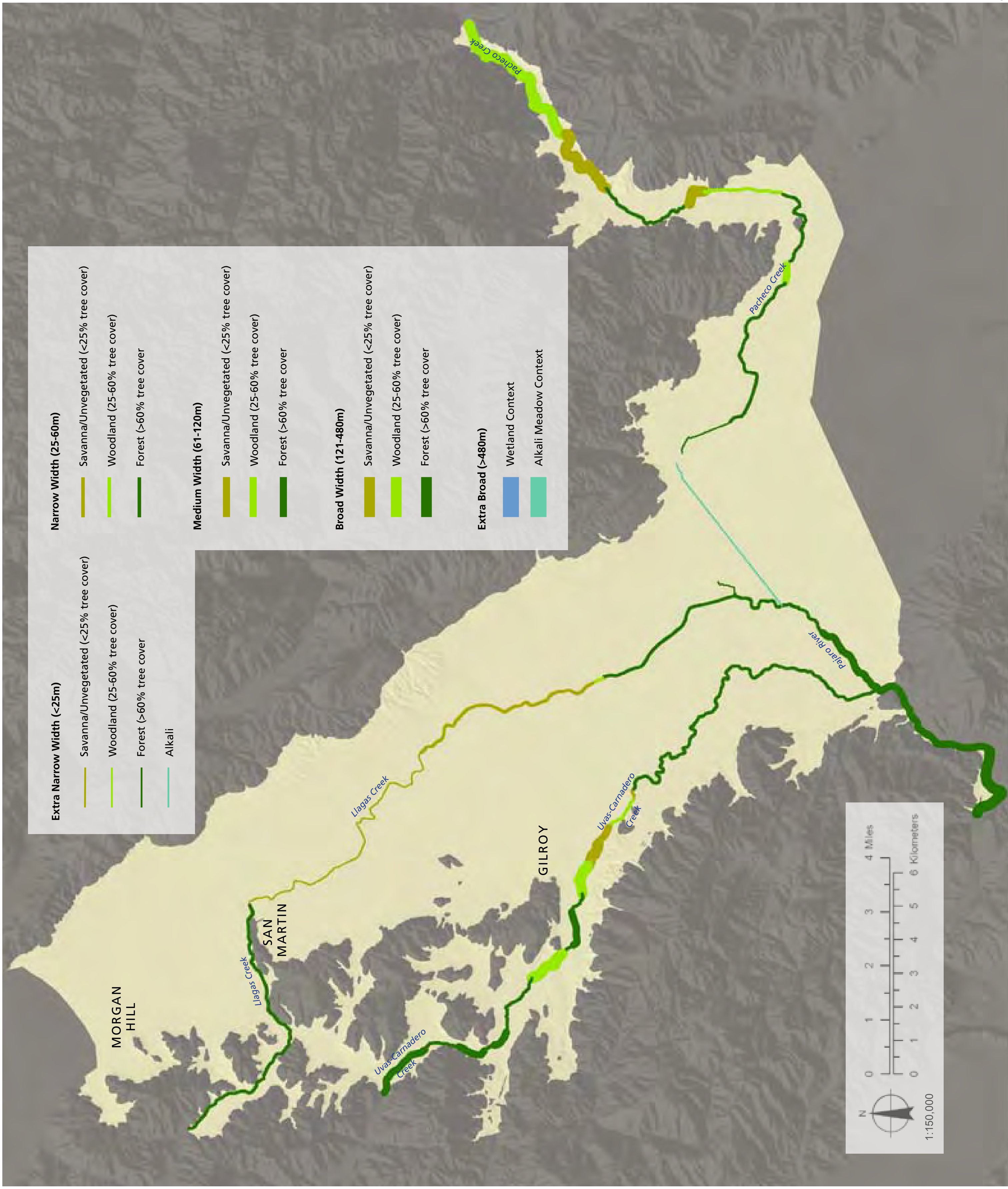


Figure 4.13. Contemporary riparian corridor width and architecture along major south Santa Clara Valley drainages. Width and riparian architecture/type classes are discussed in the text.

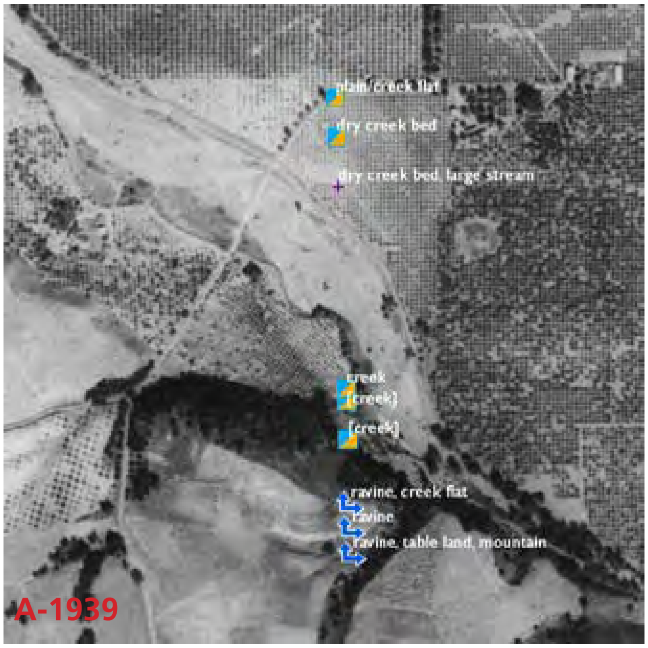


Figure 4.14. Historical reclamation of the Uvas-Carnadero Creek channel at Miller Avenue. This sequence of images compares information from four different eras. The base images are aerial photography from 1939 (A) and 2005 (B), and a county survey by Herrmann from 1875 (C). Overlaid on each of the images are survey notes from GLO surveyor Richard Howe in 1851. Howe documents a broad active channel area with side channels and adjacent stream benches ("creek flat") before development. By 1875 some of these areas are labeled "Cultivated Land" and "Creek Field." In 1939 aerial photographs, the area of former stream benches can still be distinguished within orchard patterns; a levee protects the orchards occupying the north portion of the former active channel. Presently, residential development occupies the points on the north side of the creek previously labeled "dry creek bed," and sycamore trees from the former riparian corridor (D) can be found in the Uvas Creek Preserve parking lot and picnic area. (A: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B: USDA 2005, courtesy of NAIP; C: Herrmann 1875(?), courtesy of the Office of the Santa Clara County Surveyor)

(11 mi), including about 10 km (6 mi) of sloughs through freshwater wetlands/swamps and about 8 km (5 mi) of sloughs or swales through alkali meadows.

Several major shifts in riparian corridor architecture have taken place since historical times. The total length of forested reaches has more than doubled, while the total length of woodland reaches has decreased by about 50%. Sparsely vegetated reaches have decreased less dramatically by this measure, approximately 23%. However, while they may have a similar percent canopy cover, many of the sparsely vegetated reaches have shifted from a braided channel with widely spaced sycamore and other native trees to a flood control channel with varied patches of vegetation. (This shift is discussed further in the Riparian Community Composition section below.)

Riparian forest has expanded along the major South Valley streams, while savanna, woodland, and wetland reaches have diminished.

The dramatic conversion of the more open canopy reaches (savanna and woodland) to densely forested reaches can be seen on Uvas-Carnadero, Llagas, and Pacheco creeks (figs. 4.16B-D, 4.17, 4.21, and 4.26), where the increase in forested length ranges from 212% to 591%.

The expansion of riparian forest has occurred in two different landscape settings. Downstream of major dams, notably on Uvas-Carnadero and Llagas creeks, riparian woodland and savanna have converted to riparian forest (figs. 4.16B and 4.16C), presumably as a result of an increase in dry season flow and reduced winter scouring floods, which have allowed riparian vegetation to colonize formerly open channel surfaces. In these areas, the shift in hydrologic regime has caused a downstream extension of the extent of riparian forest.

A different landscape trajectory has caused the development of forested reaches at the downstream end of Pacheco, Llagas, and Uvas-Carnadero creeks. Here historical wetland reaches, where streams spread through multiple small channels within freshwater marshes and

Figure 4.15. Llagas Creek at Church Street percolation ponds. To reduce flooding, the channel has been excavated and levees constructed on the former alluvial benches. Some of the riparian sycamore trees visible in 1939 (A) persist in 2005 (B), now isolated from the channel and floodplain. (A: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B: USDA 2005, courtesy of NAIP)

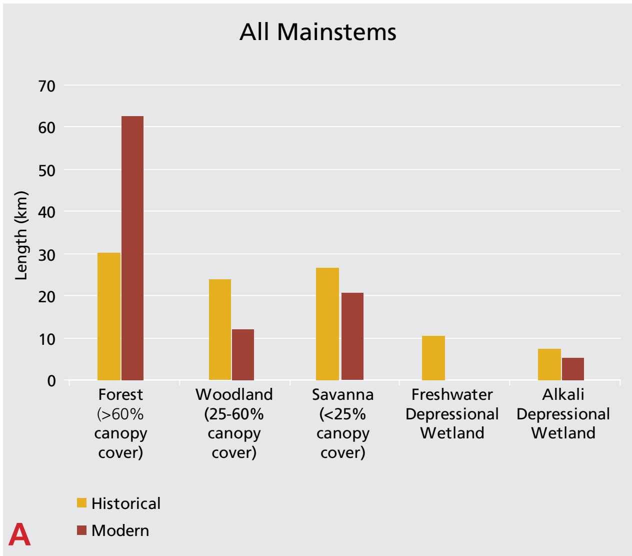
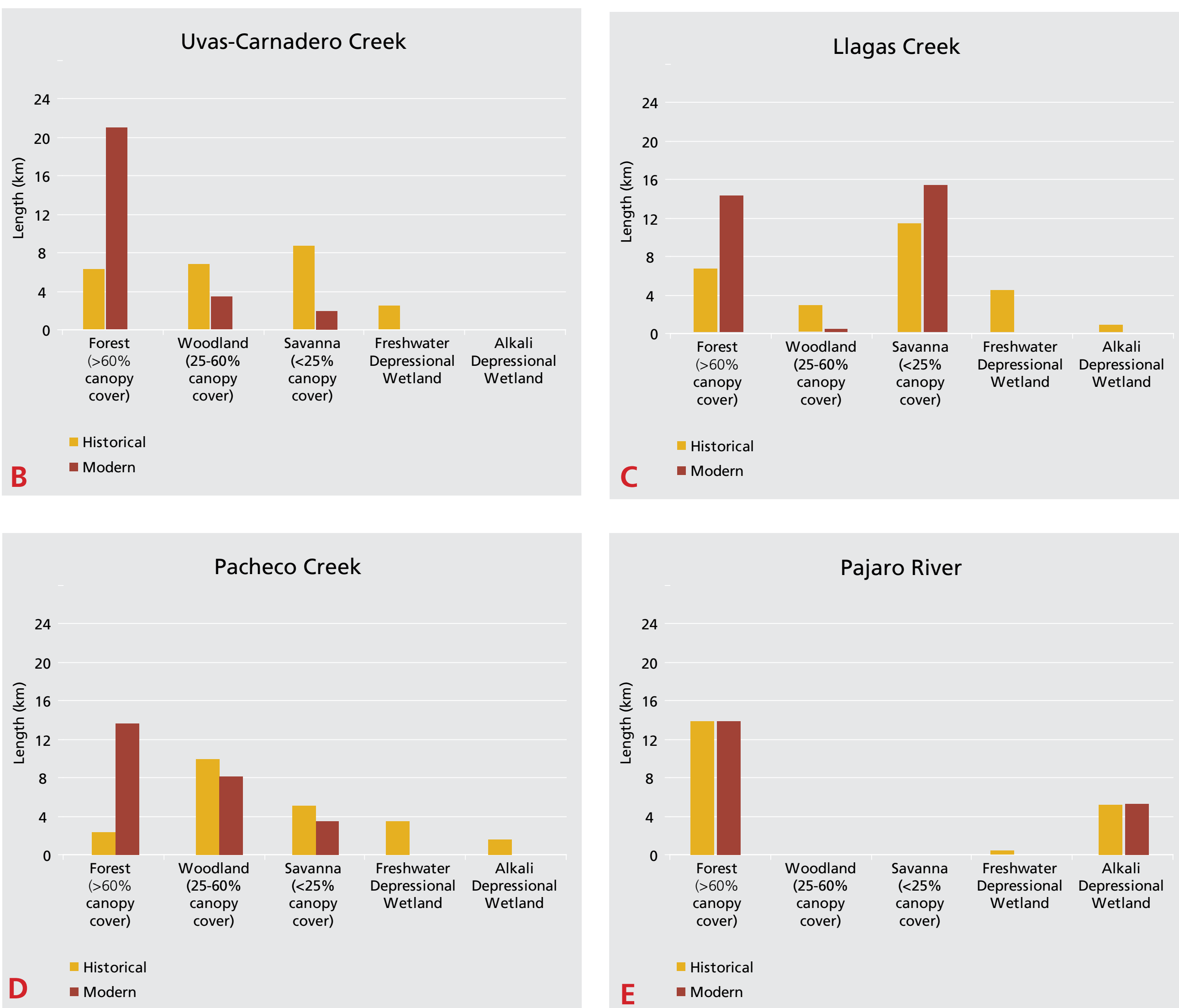


Figure 4.16. Total length of different riparian corridor types, past and present, on the Uvas-Carnadero, Llagas, Pacheco creeks and Pajaro River. Measurements are limited to the alluvial, valley floor mainstem reaches.



willow groves, have been confined to more well-defined channels. These channels tend to fill with riparian vegetation, especially willows, due to high groundwater levels and low stream gradient, establishing narrow, densely-forested channels (fig. 4.18).

In the summer of 1829, traveler Alfred Robinson "came to a river, which had been concealed till now by the density of the trees. It was the River 'Pajaro'..."

Noting that the sparsely vegetated reaches of Llagas Creek are largely flood control channel, Pacheco Creek retains the greatest proportion and amount of historical savanna and woodland reaches (fig. 4.16D). Riparian conversion has been mostly limited to the wetland reaches on Pacheco Creek, while woodland and savanna reaches have been substantially preserved. However, aerial photography seems to suggest that these areas are gradually converting to a more densely wooded, confined stream channel separated from the adjacent floodplain (see fig. 4.32). The Uvas-Carnadero Creek also retains some substantial open canopy reaches (fig. 4.16B).

Another major change is the loss of freshwater wetland reaches. These have disappeared almost completely from each of the drainages.

Some channels still flow through alkali meadows and thus could be considered alkali reaches. For example, the diffuse drainage between San Felipe Lake and the beginning of the well-defined Pajaro River channel (at the Llagas Creek confluence) was the most prominent alkali meadow reach. Millers Canal now carries most of the drainage through this area and has little riparian tree canopy on its banks, presumably because of the persistent effects of salt-affected soil. However the excavated channel is also more separated from the surrounding floodplain than the historical slough/swale system.

Most of the upper Pajaro River has experienced little change in its basic riparian corridor architecture. The reach between Llagas Creek and San Benito River appears to have been densely forested under historical conditions and remains so today. (However, other changes, such as channel aggradation, may have taken place.)

Historical evidence consistently describes the Pajaro River as having riparian characteristics distinct from other South Valley streams. In contrast to the characteristic sycamore or willow/tule swamp reaches of Llagas, Uvas-Carnadero, and Pacheco creeks, the upper Pajaro River had a dense, mixed riparian forest canopy typically associated with reliable dry season flows.

Riparian plant community composition

GLO bearing tree data, textual descriptions, landscape photographs, early maps, and aerial photography paint a consistent picture of large-scale riparian habitat variation within south Santa Clara Valley. Along the major streams of the valley floor, excepting the Pajaro, the most prevalent riparian tree was California sycamore. Sycamores were the dominant tree of the open canopy (grassland/savanna/woodland) intermittent alluvial reaches of Uvas-Carnadero, Llagas, and Pacheco creeks. Oaks, cottonwoods, willows, and other native trees were occasional species. At the lower and upper ends of the valleys, where streams were more perennial, and along the Pajaro River, sycamores became a component of a more hydrophilic, mixed riparian forest dominated by willows, cottonwoods, and oaks.

"the belts of stately sycamore had not yet shed a leaf..."

– BAYARD TAYLOR, IN LATE SUMMER 1850

This distributional pattern corresponds with previous observations that sycamore alluvial woodland is most common immediately downstream of canyon mouths, where high-energy flood flows are able to spread broadly

Figure 4.17. Llagas Creek between Santa Teresa Boulevard and Monterey Road. Historically, this reach was the transition point between a densely wooded riparian corridor and a more open or scattered riparian canopy. This transition corresponds to the shift from relatively narrow, meandering channel to a braided channel morphology as the stream outwashes onto the broad alluvial plain. Stream flow regulation has converted this reach to densely forested in the past few decades. (A: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B: USDA 2005, courtesy of NAIP)

Figure 4.18. Dense riparian corridor of willow trees on the lower Llagas Creek flood control channel. The trees have established in the past few decades, within the historical extent of a much larger willow grove.

across floodplains (Keeler-Wolf et al. 1996). It is in this landscape position that gravel beds and bars can be redistributed, stimulating the regeneration of sycamores, yet seasonal flows quickly percolate to subsurface flow. These findings also match similar patterns observed in the neighboring Coyote Creek watershed (Grossinger et al. 2007).

While sycamores were often the dominant tree along the broader South Valley streams, their density varied greatly according to setting, from widely spaced, occasional single trees (Llagas Creek) to large woodland groves composed of relatively densely spaced trees (Pacheco Creek, Uvas Creek).

Several corroborating lines of evidence indicate the prevalence of sycamores on South Valley streams. Sycamores were almost the exclusive tree recorded by 19th-century surveyors along the major open valley alluvial portions of Pacheco, Uvas-Carnadero, and Llagas creeks. Of the 50 trees noted between the beginning of wetlands on the downstream end of each stream and the beginning of dense riparian forest on the upstream end of each, 37 (74%) were sycamores (fig. 4.19). Available quotes reaffirm this pattern (fig. 4.19). For example, Day (1854), describing the timber resources for a section near Gilman Road, refers to “sycamore[s] along the Llagas” (Day 1854). Similarly, Taylor, overlooking the South Valley in 1850, described “the belts of stately sycamore.” Valley oaks were also used in several places along these reaches, confirming a common minor component of these habitats and reinforcing a picture of relatively xeric summer conditions.

Historical landscape photographs (1890s) illustrating these stream reaches consistently show broad, mostly unvegetated low bars and terraces occupied by occasional large sycamore trees (fig. 4.20). These illustrations and 19th-century textual accounts are extremely consistent with the patterns observed in 1939 aerial photography, which shows the same reaches several decades later but prior to the construction of the dams and flood control projects. Despite increasing modification, general patterns remain similar in 1950 and 1963 aerial photography. The consistency across many decades suggests that these general vegetation patterns are not the result of short-term flood disturbance.

The soil survey of south Santa Clara County conducted in 1923 also supports the presence of open, sycamore-dominated riparian corridors along many of the area’s stream reaches. Cosby & Watson (1927a) mapped Yolo fine sandy loam along many of the floodplain benches and low terraces along local streams, describing the unit as "a recent alluvial deposit along the major streams in all parts of the area except the northwestern [upper Llagas, which was relatively narrow to map]." They report that "the native vegetation on Yolo fine sandy loam consists mainly of grasses and sycamore and oak trees." Similarly, the "River wash" unit is described as "sandy and gravelly channels...dry and devoid of vegetation, except for scattered sycamore trees, clumps of willows, and a few rapidly growing wild plants and vines." Together these soils correspond to most of the broadest braided channel reaches in the study area, including Uvas-Carnadero Creek (from Miller Avenue to the confluence of Little Arthur Creek), lower Bodfish Creek, Llagas Creek (from Church Street to El Camino Real), and the braided portion of Pacheco Creek. It is likely that similar units occur along narrower braided reaches too small to map. Vegetation of the "Riverwash" type is described similarly in the contemporary soil survey of south Santa Clara County, conducted in 1960-65: "willows, sycamore trees, oak trees, herbs, and clumps of perennial and annual grasses" (Lindsey 1974). Fast growing wild vines were also reported from other sources. Wild grapes and Coast wild cucumber were common along the Uvas, especially upstream of the Bodfish Creek confluence (Harrington 1929); the former led to the stream's name. Local residents recollect that before modern flood control modifications, there were sycamores and a few cottonwoods on the Llagas near Rucker Ave, where sycamores "were huge, but they weren't dense" (D. Sturla pers. comm.).

Within these reaches, there was likely finer scale variation associated with perennial pools, differences in bank material, and other factors.

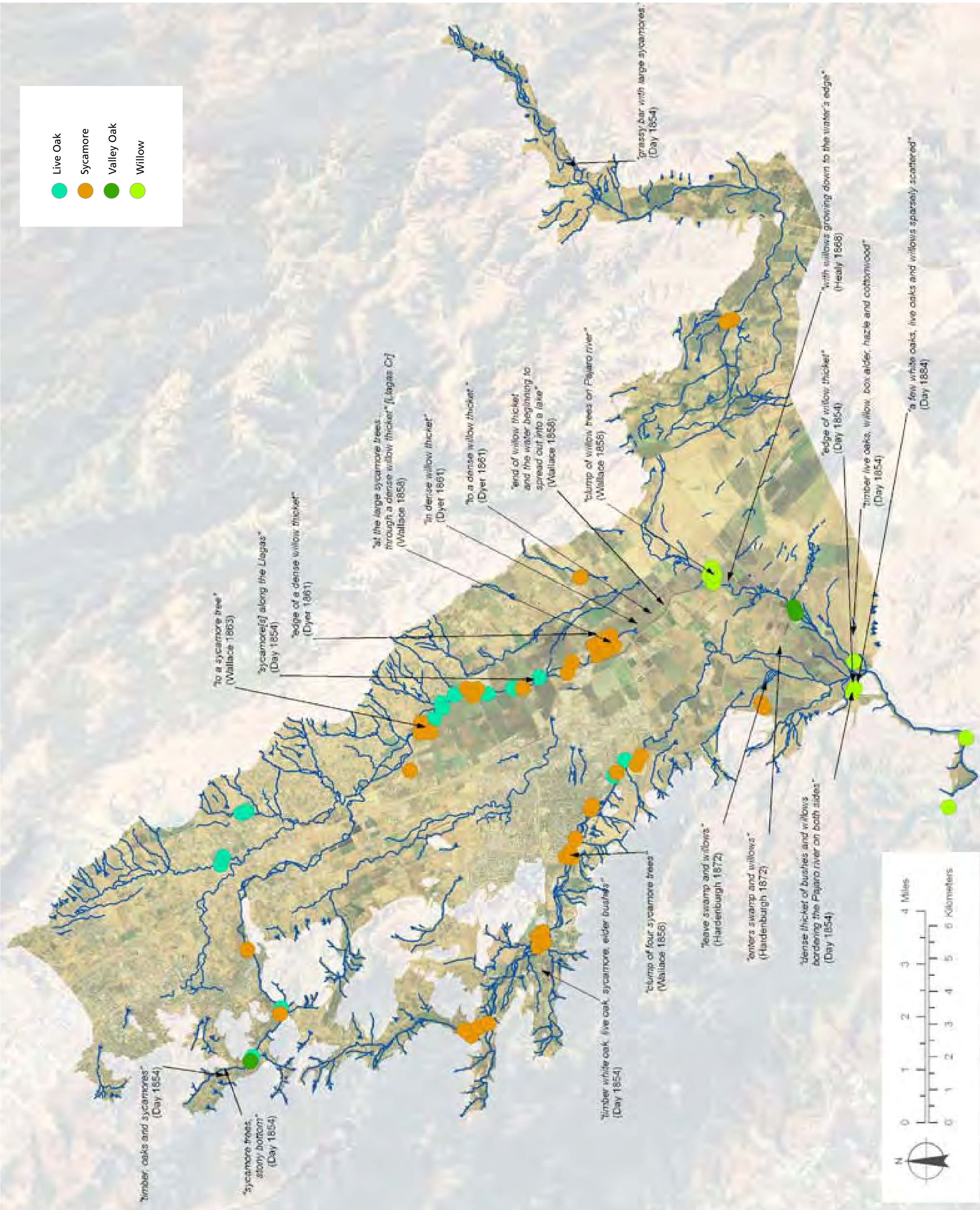
Sycamore-dominated braided river channels exhibited several different riparian architectural styles. Along more narrow braided reaches, occasional sycamores were spaced widely (commonly 50 to 100 m/160-330 ft apart) along the channel. In contrast, large groves of 10 to 50 trees were frequent on reaches with broad gravel bars or islands. For example, Llagas Creek maintained for much of its length a braided channel with relatively narrow islands and bars often supporting one to several trees (figs. 4.21 and 4.15). In contrast, Pacheco Creek, and some reaches of Uvas-Carnadero, formed much broader islands and benches providing habitat for many mature trees (figs. 4.21 and 4.22).

Based on these data, we estimate that, on the main stems of Uvas-Carnadero, Llagas, and Pacheco main creeks, there was a total of at least 35 km (22 mi) of braided channel with California sycamore as the dominant riparian tree. About 10 km (6 mi) of the historical sycamore-dominated braided channel was made up of large stands that could be considered to meet the criteria of Keeler-Wolf et al. (1996) for Central California's Sycamore Alluvial Woodland (CCSAW) (>10 ac). Most of the CCSAW was found along Pacheco Creek, but a small amount (~1.5 km/1 mi) was existed on Uvas Creek.

> *"...a fair-sized river which runs through a heavy growth of cottonwoods, willows, and sycamores, with a good volume of water..."*
>
> — PALOU 1774, DESCRIBING THE PAJARO RIVER

Of the 35 km of sycamore-dominated braided channel, relatively little remains today because of modifications to Llagas and Uvas-Carnadero creeks. Remarkably, however, the CCSAW portion remains fairly intact at this time, because many of the stands along Pacheco Creek have

Figure 4.19. Bearing trees and textual descriptions from 19th-century GLO and county surveys. Survey dates range from the 1850s to the 1890s, with most of the data collected between 1851 and 1861. Willow trees were probably only used for bearing trees as a last resort, where more long-lived trees were not immediately available (such as some sites along the upper Pajaro). Sycamores, with some valley oaks, were used along braided channel stream reaches. Cottonwoods are notably absent as bearing trees but occasionally mentioned as part of the mixed riparian community along the upper Pajaro and the Uvas.



Live Oak
Sycamore
Valley Oak
Willow
"grassy bar with large sycamores" (Day 1854)
"with willows growing down to the water's edge" (Healy 1868)
"a few white oaks, live oaks and willows sparsely scattered" (Day 1884)
"edge of willow thicket" (Day 1854)
"timber live oaks, willow, box alder, hazle and cottonwood" (Day 1854)
"clump of willow trees on Pajaro river" (Wallace 1856)
"end of willow thicket and the water beginning to spread out into a lake" (Wallace 1858)
"to a dense willow thicket" (Dyer 1861)
"in dense willow thicket" (Dyer 1861)
"at the large sycamore trees through a dense willow thicket" [Llagas Cr] (Wallace 1858)
"edge of a dense willow thicket" (Dyer 1861)
"sycamore[s] along the Llagas" (Day 1854)
"to a sycamore tree" (Wallace 1863)
"timber, oaks and sycamores" (Day 1854)
"sycamore trees, stony bottom" (Day 1854)
"timber white oak, live oak, sycamore, elder bushes" (Day 1854)
"clump of four sycamore trees" (Wallace 1856)
"leave swamp and willows" (Hardenburgh 1872)
"enters swamp and willows" (Hardenburgh 1872)
"dense thicket of bushes and willows bordering the Pajaro river on both sides" (Day 1854)
0 1 2 3 4 Miles
0 1 2 3 4 5 6 Kilometers
N

Figure 4.20. Historical landscape photographs of braided, gravelly, sycamore-dominated South Valley streams. Each shows wintertime flow in the mainstem channel, stand-alone sycamores without leaves, and limited other vegetation. These photos can be positioned as follows: (A) Uvas Creek looking towards the Hecker Pass Highway Bridge near the Bodfish Creek confluence, 1894; (B) Llagas Creek near the Monterey Road/Southern

Pacific Railroad crossing, 1895; (C) Llagas Creek north of Gilroy, 1895; and (D) Llagas Creek between Buena Vista and Rucker avenues, 1895. (A: Unknown 1894a, courtesy of Matt Kondolf and the Gilroy Museum; B: Hill & Yard ca. 1895, courtesy of the Morgan Hill Historical Society; C: Unknown ca. 1896a, courtesy of History San José; D: Unknown 1895, courtesy of the Gilroy Museum)

Figure 4.21. (A, B) Widely spaced sycamore trees (a, b) along the shallow, multithread Llagas Creek channel immediately downstream of the Monterey Road and railroad crossing. (C, D) A grove of sycamore alluvial woodland (c) on a mid-channel bar in Uvas Creek at Watsonville Road (d). In both cases, riparian forest has expanded within a narrower active channel during recent decades. (A and C: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B and D: USDA 2005, courtesy of NAIP)

persisted (fig. 4.24; Keeler-Wolf et al. 1996, Jones and Stokes 2006).

Historical records of the Pajaro River contrast starkly to these sycamore-dominated stream reaches. These descriptions vary in their detail but consistently indicate a more mixed, dense, and hydrophilic riparian forest. For example, Healy (1868) refers to "willows growing down to the water's edge." In 1769, Crespí reported "a fine little river with a fair-sized bed and a great many willow trees, sycamores and other timber"

Figure 4.22. Sycamore alluvial woodland on the braided Pacheco Creek channel. Between 1939 (A) and 2005 (B) the main channel has migrated substantially. (A: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B: USDA 2005, courtesy of NAIP)

(Stanger and Brown 1969), while five years later in 1774, Palou noted "a fair-sized river which runs through a heavy growth of cottonwoods, willows, and sycamores, with a good volume of water" (Bolton et al. 1930). Day (1854) described "timber live oaks, willow, box alder, hazle [sic] and cottonwood." Men on a boat adrift in the Pajaro in 1852 "managed to catch hold of some branches" on the "South Bank of the Pajaro among the willows and cottonwood trees" (Roddy 1995), while Broek (1932) noted that "a string of sycamores and willows forms a landmark clearly seen at a considerable distance." With some expected variation that may be explained by reach-scale variation (see Chapter 7), GLO bearing trees (see fig. 4.19), landscape photography (see figs. 4.24 and 4.25) , and early aerial imagery each corroborate the historical mixed riparian forest community on the upper Pajaro River. Similarly, the narrower, more perennial reaches of Uvas-Carnadero, Llagas, and Pacheco creeks at the top and bottom of the valley had more mixed and dense riparian communities. For example, Solarsano (Harrington 1929) described cottonwoods and willows along Uvas Creek at Gilroy, probably referring to the narrower, more densely wooded reaches upstream of the Bodfish Creek confluence (or downstream of Miller Avenue).

Intermittent vs. perennial reaches

We found about 30 quotes describing dry season flow conditions between 1774 and 1923 (table 4.1, fig. 4.23). These quotes consistently characterize streams throughout the valley floor as intermittent, with the notable exception of the Pajaro River. While surface flow was highly restricted during the summer, there is evidence of scattered summer pools connected by strong subsurface flow. At least some of these were sufficiently persistent and reliable to serve as summer refuges for native fish, and fishing and swimming holes for local residents. Observers recognized that while flow would inevitably "sink in the gravel of the valley creek-beds,"

Figure 4.23. Historical evidence for dry season stream flow.

Table 4.1. Historical evidence for dry season stream flow.

Stream	Reach	Date	Evidence	Reference
Uvas-Carnadero	Hwy 101 bridge	July 1874	"dry bed of the creek"	San Benito Advance 1874
Uvas-Carnadero	2 mi outside of Gilroy (west, possibly south)	1897	"dry bed of the Carnadero"	Kenderdine 1898
Uvas-Carnadero	Bodfish confluence	1888	"there will be no stream here—only a sand and gravel bed"	Harrison ca. 1888
Uvas-Carnadero	—	ca. 1880?	"dry up every year"	Ascensión Solorsano, in Harrington 1929
Uvas-Carnadero	Christmas Hill SW of Gilroy	Nov. 1851	"dry creek bed, quite a large stream in wet weather but now dry"	Howe 1851
Uvas-Carnadero	Thomas Road	July 9, 1854	"Creek is dry this time of year"	Thomas 1954
Llagas	Leavesley Rd N of Old Gilroy	1867	"dry bed of the Arroyo de las Llagas"	Upson 1867
Llagas	S of Gilman Rd, N of Old Gilroy	June 1854	"gravelly bed, now dry"	Day 1854
Llagas	North of San Martin	Nov 1774	"water only in pools, but it is seen that in the rainy season it has a large flow"	Palou 1774, in Bolton et al. 1930
Llagas tributary	—	late June/ early July 1849	"Dan pulled out from a limpid pool delightful salmon-trout, full two feet in length"	Wise 1850
Llagas	North of San Martin	1855	"There is water on the place [Posa de Las Llagas, an in-stream pool] all the year around and people traveling about there were in the habit of camping there"	Pinto 1855b
Llagas	—	184-?	"Arroyo Seco"	U.S. District Court, Northern District [184-?]d
Pajaro	Just above Llagas Creek confluence	Sept 1861	"a stream the bed of which is now dry"	Dyer 1861
Pajaro	Reach from Sargent to San Benito River	1896	Photograph and description that the "River can be navigated with row boats a distance of two miles below the station"	Shortridge [1896]1986
Pajaro	—	1868	"Water moves very sluggishly"	Healy 1868
Pacheco	—	1868	"dry, plantless flood-beds of gravel and sand"	Muir [1872]1974

water was often present not far below. The phenomenon of water underneath rather than above the gravel was even recognized in a common saying, that "many of the California streams are upside down" (Shortridge [1896]1986).

Most of these data precede significant dams, diversions, or groundwater depletion for agricultural use. Irrigation, and associated water withdrawal, did not expand in south Santa Clara Valley until after 1900 (Cosby & Watson 1927a). These data are also consistent with the one long-term gauging record in the region, on Coyote Creek at Madrone (just north of the study area), which shows zero or near zero flow during June through November prior to the construction of Coyote Dam (McKee et al. 2003, Grossinger et al. 2006).

Both general overview descriptions of the region and specific, local observations confirm this pattern. In the early 1920s, researchers Stanley Cosby (UC Berkeley) and E.B. Watson (USDA) investigated south Santa Clara Valley to evaluate agricultural potential as part of the Soil Survey of the Gilroy Area. (The phrase "Gilroy area" referred to the entire upper Coyote Creek-Morgan Hill-Gilroy area, as Morgan Hill was only a minor town at this time.) Cosby and Watson wrote: "Most of the creeks of the Gilroy area are intermittent," noting that "after the run-off of the winter flood waters their sandy and gravelly channels are dry and devoid of vegetation, except for scattered sycamore trees, clumps of willows, and a few rapidly growing wild plants and vines" (Cosby & Watson 1927a).

William O. Clark of the USGS (1924) evaluated groundwater conditions in the entire Santa Clara Valley around the same time. Based upon his fairly extensive investigations, he stated: "All the streams in Santa Clara Valley are intermittent. Their courses through the valley are usually dry from four to eight months of the year, and occasionally water flows throughout the length for only a few days in the year or perhaps not at all." He also noted that, accordingly, "surface water is never available for irrigation in summer" (Clark 1924). Clark also emphasized the episodic or flashy nature of Santa Clara Valley streams, using flow records for Coyote and Alameda creeks, the two local creeks with substantial gauging records at that time. He noted the rapid rise and fall of the hydrograph associated with individual storm events in cycles as brief as three days.

> *"The arroyos run for a time and dry up and the water remains dammed up in certain pools and that is where the fish remain."*
>
> — ASCENSIÓN SOLORSANO, 1929

These early 20th-century scientific analyses of the region are corroborated by extensive 19th-century and limited 18th-century sources about individual creeks. While several of these observations are associated with dry years (1851, 1898) most are associated with average or above average rainfall years. A number of these quotes indicate intermittent conditions quite early in the summer, such as Sherman Day's observation of lower Llagas Creek near Bloomfield Avenue as dry by June 28 in 1854, an average water year.

Descriptions of intermittent conditions on Llagas Creek suggest that it was probably intermittent from at least the area where it opens into the broad alluvial plain, alongside the Silveira Hills outcrop, to some point near or at the beginning of the willow swamps near Pacheco Pass Road. Broek (1932) wrote that "Llagas Creek draining to the south has, like the Coyote, seldom a water stream." In November 1774 an exploring party near the low spur of hills just north of San Martin noted that Llagas Creek had "water only in pools, but it is seen that in the rainy season it has a large flow and that the rainfall of the valley must collect in this river" (Palou 1774, in Bolton et al. 1930). In this same area was a significant Mexican-era landmark called "Poza [pool] de las Llagas" or simply "Las Llagas," a stopping place that was just off of the old road connecting San José to Monterey (west of the current Monterey Road alignment). The area was noted for its perennial pool—in an otherwise often dry stream—that provided water to travelers: "There is water on the place all the year around and people traveling about there were in the habit of camping there" (Pinto 1855a). In June, Llagas Creek south of Gilman Road (outside of Gilroy) was described as a "gravelly bed, now dry" by GLO surveyor Day (1854). Another GLO surveyor noted that the channel of lower Llagas Creek slightly north of the site of the previous quote (at Leavesley Road) was also a "dry bed" (Upson 1867). The transition from intermittent stream to swamplands occurred within a relatively short distance: Sherman Day described the dry gravelly bed with sycamores near Gilman Road just a mile upstream of the willow groves and tule marshes of lower Llagas.

Evidence suggests that much of the valley floor portion of Uvas-Carnadero Creek was also intermittent. In mid-July 1874, a man fell from the Carnadero Bridge (likely at or near the current Highway 101 bridge) "into the dry bed of the creek, a distance of 30 or 40 feet" (San Benito Advance 1874). A GLO surveyor, crossing Carnadero Creek in November at Christmas Hill southwest of Gilroy, noted his experience with the creek's seasonality: "Cross the dry creek bed, quite a large stream in wet weather but now dry" (Howe 1851).

Some of these reaches were so predictably intermittent that farmers incorporated the dry, sandy or gravelly creek beds into their agricultural practices. One farmer along Uvas-Carnadero Creek two miles outside of Gilroy used the dry bed of the creek to his advantage: "The ranch was along the dry bed of the Carnadero river. Water is nicer than sand for scenery, but for fruit-drying the last is better" (Kenderdine 1898).

Even further upstream at Uvas Creek, the stream was seasonally dry. Harrison (ca. 1888) writes of Uvas Creek in the vicinity of the Bodfish confluence:

> There is every evidence that during the rainy season it is a writhing, seething, roaring torrent, but just now its pellucid waters flow over their gravelly course as harmless as a babbling brook; and bye-and-bye, when the dry season has changed the aspect of nature, there will be no stream here—only a sand and gravel bed.

In the 20th century, but prior to the construction of Uvas Dam, Uvas Creek was consistently perennial downstream as far as Adams School but not far below (Sturla pers. comm.). The Adams School-Chitactac site corresponds with the historical shift from narrow, forested stream to broad, braided, less densely wooded stream as the valley bottom widens. This would have been an ideal site for a bedrock acorn milling station such as Chitactac, with reliable summer water (see fig. 3.2). Bodfish Creek also "never ran continually to Uvas" during the summer (Sturla pers. comm.).

Less evidence was discovered for Pacheco Creek, but similar descriptions were found, corresponding to braided, sparsely vegetated riparian habitats consistent with intermittent conditions. Traveling along Pacheco Pass Road in 1868, John Muir noted Pacheco Creek's "dry, plantless flood-beds of gravel and sand" (Muir [1872]1974). In August of 1858, GLO surveyor Washington described Pacheco as "a dry creek," while a local resident recalls that "Pacheco never ran all year" (Sturla pers. comm.).

In contrast to the uniformly consistent accounts of intermittent streams throughout the rest of south Santa Clara Valley, the Pajaro River stands out as having different characteristics. Near Sargent, Pajaro is described as "softly-flowing" with its banks "covered with alders and willows" (Shortridge [1896]1986). Shortridge notes that the river "can be navigated with row boats a distance of 2 miles below the [Sargent] station (approximately to the San Benito confluence)," a recreational activity indicating substantial summer water (figs. 4.24 and 4.25).

About 40 years earlier Sherman Day, who described numerous other streams in the valley as dry on the same survey, corroborated the presence of substantial summertime flows. He describes in June near the present-day Carnadero confluence a "copious running stream

Figure 4.24. "Scene on Pajaro River, near Sargents." This photograph and the following (fig. 4.25) both show the Pajaro River between Sargent and Betabel Station. Substantial summer water is suggested by navigable conditions while deciduous trees are in leaf. (Unknown ca. 1896b, courtesy of History San José)

25 links [5 m/16.5 ft] wide." The description is notable not only for its contrast to his frequent arid stream descriptions, but also because he indicates that the wetted channel surface is about 5 m wide. In early October 1769, Crespí (Stanger and Brown 1969) described "a fine little river." County surveyor Healy (1868), following the river to establish the county line, described it as a willow-lined slough with substantial water:

> ...above the junction of the San Benito, the Pajaro has more the characteristics of a slough than a river. The water moves very sluggishly in a very deep, narrow channel, averaging 75 links [15 m/50 ft] in width, with no bluff banks, but with willows growing down to the water's edge.

The Pajaro River appears to have been a rare regional instance of the more meandering, single thread, perennial river ideal (Kondolf 2006), in stark contrast to the dominant local stream types. This led to evocative descriptions characteristic of a low-gradient, densely-wooded perennial system: "The river at this point flows very gently, and the overhanging trees and windings of the river make the river scenery very beautiful"

Figure 4.25. "Pajaro River near Sargent and Betabel station." (Unknown ca. 1890c, courtesy of the San Benito County Historical Society)

(Shortridge [1896]1986). This distinctive reach, extending between the Llagas Creek and San Benito River confluences, had sharp boundaries. Downstream of the San Benito confluence, the Pajaro River's channel form was dominated by the San Benito, as both were described as "broad sandy streams" (Healy 1868).

Perennial conditions probably extended upstream along the Pajaro as far as the dense riparian forest evidenced by mid-19th-century surveys and early aerial photography. Just above the modern confluence of Llagas Creek with the Pajaro River, at the head of the river where it formed from a series of seasonally dry sloughs, a GLO surveyor recorded that the river was "now dry" in September (Dyer 1861).

Tributary streams were also consistently described as dry in the summer. For example, Jones Creek was labeled "Dry Creek or Arroyo Seco" on an 1852 survey of part of Rancho San Ysidro (Lewis 1852). Some may have had perennial, or at least more persistent, flow immediately downstream of their canyon mouths, such as Martin Creek – noted by Day (1854) as "running stream" in early July. Flow at this site, however, may have been associated with the surrounding wet meadow and "marshy swales" (Day 1854). At least some small tributary streams had pools persisting into the summer: "water in pools, scarce" (on Corralitos Creek and San Ysidro Creek in July, Day 1854). While this study did not examine evidence for dry season flows within the upper watersheds, many of the streams likely had more perennial reaches just upstream from the valley floor. Sherman Day provided a clear illustration of the difference in summer hydrology between canyon and alluvial fan, crossing San Ysidro Creek twice on June 28, 1854. While he described the stream as a "dry run with gravelly bottom" 50 links (10 m/30 ft) wide just downstream from the canyon mouth, when he encountered the curving creek again less than a kilometer away he reported "Arroyo… 40 links [8 m/25 ft] wide, with stony bed, water in pools. Sycamores along the bank." (Day 1854).

Historical accounts demonstrate that perennial pools on the intermittent reaches of mainstem creeks in the area maintained significant aquatic resources, including suckers, steelhead, and other fish. J.P. Harrington, a linguist and ethnographer, interviewed Mutsun speaker Ascención Solorsano (born in the mid-1840s) about her experiences living in the San Juan Bautista and southern Santa Clara Valley area. Solorsano recounted stories of fishing with her hands on the Uvas and San Benito Rivers, noting the locally distinctive summer flow conditions on the Pajaro:

> When the water is already low in the rivers is the time that one can fish with one's hands in the caves under the steep banks. I used to fish in this way almost every year in Uvas Creek and the San Benito River, in these two rivers only it was good to fish in this way because the water went down much in the summer, but the Sargent River [Pajaro] was not good for fishing with one's hands for the water was very deep all the time…The fish that one can catch with the hands are the suckers, the kind of trout that are called pikes, and a salmon trout or two. Once at Uvas Creek I got an eel and was very much frightened. I thought it was a snake. (Harrington 1929)

Fish were abundant under these conditions: Solorsano explained that one "just reaches his hand in and seizes the fish by the gills" (Harrington 1929).

Pools fed by subsurface flows played an important role for both fish and fishermen during the summer. A traveler in 1849 describes going fishing during the summer with his host, Dan Murphy, on what was likely a tributary to Llagas Creek: "Dan pulled out from a limpid pool delightful salmon-trout [steelhead], full two feet in length" (Wise 1850). Solorsano also explained the optimal conditions for catching fish in these pools, at the same time describing the pattern of persistent pools connected by subsurface flow within an intermittent reach:

> …It has to be where the water is dammed up and does not have a current even though it runs underneath the sand… They never make a dammed-up place in the arroyo, but merely hunt where the water is already dammed up. The arroyos run for a time and dry up and the water remains dammed up in certain pools and that is where the fish remain and they poison them…I saw them do this and [sic] Las Uvas Arroyo, at Coyote Arroyo, these are the arroyos that dry up every year. (Harrington 1929)

Again, Solorsano mentions Uvas Creek as a stream that seasonally dries, "though [the water] runs underneath the sand." These pools provided a wet, low temperature, safe (if not from fishermen) oversummering habitat even as the rest of the creek ran dry. Pools appear to have been well-connected to near-surface flow and had enough inter-annual reliability to support consistent traditional practice.

Specific large pools were an often noted feature on southern Santa Clara Valley streams, used for fishing and swimming. Lower Pacheco Creek had several, including a big pool probably near Pacheco's old adobe (near the modern Highway 156 crossing) and two others, used as the boys' and girls' swimming holes in the late 19th century, near the San Felipe area (Milliken n.d.; Williams 1968a,b). A large pool at the confluence of the Pajaro and San Benito rivers figured prominently into local culture. Called "La Poza" by Solorsano, she recalled that "they used to fish at night" on rowboats at the pool. Llagas Creek, with its longer alluvial reach, may have had fewer reliable pools downstream of "Poza de las Llagas." Longtime resident Jack Sturla, whose family has lived adjacent to lower Llagas Creek for over 100 years, recollects that the stream rarely ran past his house (east of Gilroy) in late spring, but that when it did, it was "was riffle, pool, hole, all the way through."

Stream reach patterns indicated by evidence for intermittent and perennial conditions also closely match patterns observed in both riparian habitat and stream morphology, suggesting an interrelated set of natural stream processes and functions. The reaches of Pacheco, Llagas, and Uvas-Carnadero creeks documented as intermittent correspond with braided channel morphology and relatively open riparian canopies with tree species characteristic of intermittent streams.

Native Fish Assemblages

The following section uses the historical evidence for stream habitat conditions and historical records of fish in the watershed (Appendix 2) to reconstruct probable native fish assemblages associated with major habitat types (Appendix 3). The south Santa Clara Valley lies within the upper Pajaro River watershed that zoogeographically is part of the Monterey Bay Subprovince of the larger Sacramento-San Joaquin Fish Province (Moyle 2002). As such, the upper Pajaro River watershed historically supported many of the species of freshwater and saltwater dispersant, as well as endemic, fishes found in the Central Valley. The thirteen native fishes historically characterizing the upper Pajaro River watershed include Pacific lamprey, Sacramento blackfish, hitch, Sacramento pikeminnow, thicktail chub, California roach, speckled dace, Sacramento sucker, threespine stickleback, riffle sculpin, prickly sculpin, Sacramento perch, and tule perch (Appendix 3; Snyder 1912, Smith 1982, Gobalet 1990, Moyle 2002). The thicktail chub, Sacramento perch, and tule perch are now extirpated from the Pajaro River watershed (Moyle 2002).

Freshwater fishes are thought to have colonized the Pajaro River system from the Sacramento-San Joaquin Province by two routes (Moyle 2002). Geologic evidence indicates that during the middle to late Pleistocene, upper Coyote Creek may have changed course several times to flow into Llagas Creek, a tributary to the upper Pajaro River, near present day Morgan Hill (Branner 1907). Lowland forms of native fishes (i.e., Sacramento blackfish, Sacramento pikeminnow, thicktail chub, Sacramento sucker, Sacramento perch, and tule perch), as well as the riffle sculpin that is typically a headwater species, probably colonized the Pajaro watershed through these former connections with Coyote Creek, which now is tributary to southernmost San Francisco Bay. A second (presumably earlier) pathway between headwater streams in the San Benito River system, a large stream tributary to the middle Pajaro River, and streams flowing to the Tulare Lake Basin of the Central Valley, allowed California roach, Sacramento sucker, and speckled dace to colonize the watershed (Murphy 1948, Moyle 2002).

The Pajaro River watershed historically and currently supports regionally significant steelhead populations (Smith 2007a,b). From 1972 to the present, investigations by Jerry Smith have provided valuable data and analysis into the probable historical distribution and current status of steelhead in the watershed (see Smith 1982, Smith 1998, Smith 2007a,b). We used these and other data to describe native fish assemblages.

Perennial mainstem streams

The Pajaro River was historically a low-gradient, densely wooded perennial stream from its confluence with the San Benito River to its confluence with Llagas Creek (see figs. 4.24 and 4.25). Early fish collections from the Pajaro River confirm the presence of an assemblage dominated by lowland forms. Species collected from or likely to have occurred in the mainstem Pajaro River before significant environmental modifications include Pacific lamprey, Sacramento blackfish, hitch, thicktail chub, Sacramento pikeminnow, California roach, Sacramento sucker, threespine stickleback, prickly sculpin, Sacramento perch, and tule perch (Snyder 1912, Smith 1982, Gobalet 1990, Smith 2007a,b, CASICD 2008). The mainstem Pajaro River fish assemblage is similar to those found historically in similarly situated lowland riverine environments within the Central Valley and tributaries to the San Francisco Bay estuary (Moyle 2002, Leidy 2007).

Steelhead adults and smolts utilized the mainstem Pajaro River primarily as a migration corridor (Smith 2007b). The historical importance of perennial reaches of the Pajaro River for rearing steelhead is unknown, although a few rearing steelhead have been recorded in more recent times (Smith 1982). Smith (2007a) posits that the "rainbow trout" collected by Snyder (1912) from the mainstem Pajaro River were probably migrating smolts from tributary streams. Steelhead are known to rear within the perennial mainstem Cosumnes River and its floodplain in the Central Valley, indicating that low-elevation, relatively warm, perennial streams may provide suitable habitat for rearing steelhead (Moyle pers. comm.).

Large discontinuous creeks and distributaries

Large discontinuous creeks and distributaries were often transitional fluvial features, their lowermost reaches integrating into mosaics of small sloughs, willow groves, perennial freshwater marshes and ponds, seasonally wet meadows, and alkali meadows. These areas were highly variable environments characterized by broad gradients in surface water depth and persistence. Fish assemblages likely also showed great temporal and seasonal variability depending on local channel geomorphology and streamflow conditions. The lowermost reaches of Uvas-Carnadero, Llagas, and Pacheco creeks transitioned from single thread channels into small, multiple alluvial channels associated with wetlands. In several instances, the distributaries were closely integrated with valley freshwater marsh habitats at their termination points. Discontinuous creeks and distributaries most closely associated with perennial valley freshwater marsh would support fishes typical of lowland habitats. However, "drier-end" discontinuous creeks and channels characterized by ephemeral-to-intermittent surface hydrology would be more likely to support fishes such as California roach, hitch, Sacramento sucker, and threespine stickleback, contingent on local conditions. It is reasonable to conclude that these fluvial transition zones supported a mixture of species characteristic of various stream and wetland habitats, as fish moved seasonally between downstream freshwater marsh wetlands and fluvial habitats in order to take advantage of preferred environmental conditions. Depending on stream flows, steelhead adults and smolts likely used discontinuous creeks and distributaries as migratory pathways between tributary headwaters and the mainstem streams. Distributaries and discontinuous creeks could form barriers to migrating steelhead during no and low flow conditions, and could trap fish if flows rapidly declined.

Small discontinuous creeks and distributaries

Creeks with small watersheds often dissipated in undefined or multiple small channels on their alluvial fans without connecting to other creeks (see fig. 4.7). These small tributary creeks and distributaries were typically characterized by ephemeral or intermittent flows on valley floor reaches and were probably fishless, while their headwaters in the hills and canyons often maintained year-round surface water and fishes. Permanent headwaters with only occasional connections to downstream waters may have supported fishes such as California roach, Sacramento sucker, resident rainbow trout, threespine stickleback, and prickly sculpin, depending on surface water persistence and temperature. Similar fishes are found in small, discontinuous creeks in adjacent watersheds of the San Joaquin Valley and San Francisco Bay estuary (Leidy 2007). It is probable that small discontinuous creeks and distributaries typically did not function as migratory pathways for steelhead to suitable headwater habitat, except infrequently during very wet years when precipitation extended runoff to the valley floor.

Floodplain sloughs

Floodplain sloughs were closely associated with wetlands and could be either perennial or intermittent. Perennial sloughs typically were marshy, low-gradient, slow-moving or sluggish stream environments that were characterized by high width/depth ratios. An example of a perennial floodplain slough is Tequisquita Slough, which is connected hydrologically to San Felipe Lake. At one location, a cross section of Tequisquita Slough measured 3.4 m (11 ft) wide and 0.3-1.2 m (1-4 ft) deep (San Benito County Public Works 1949). Perennial

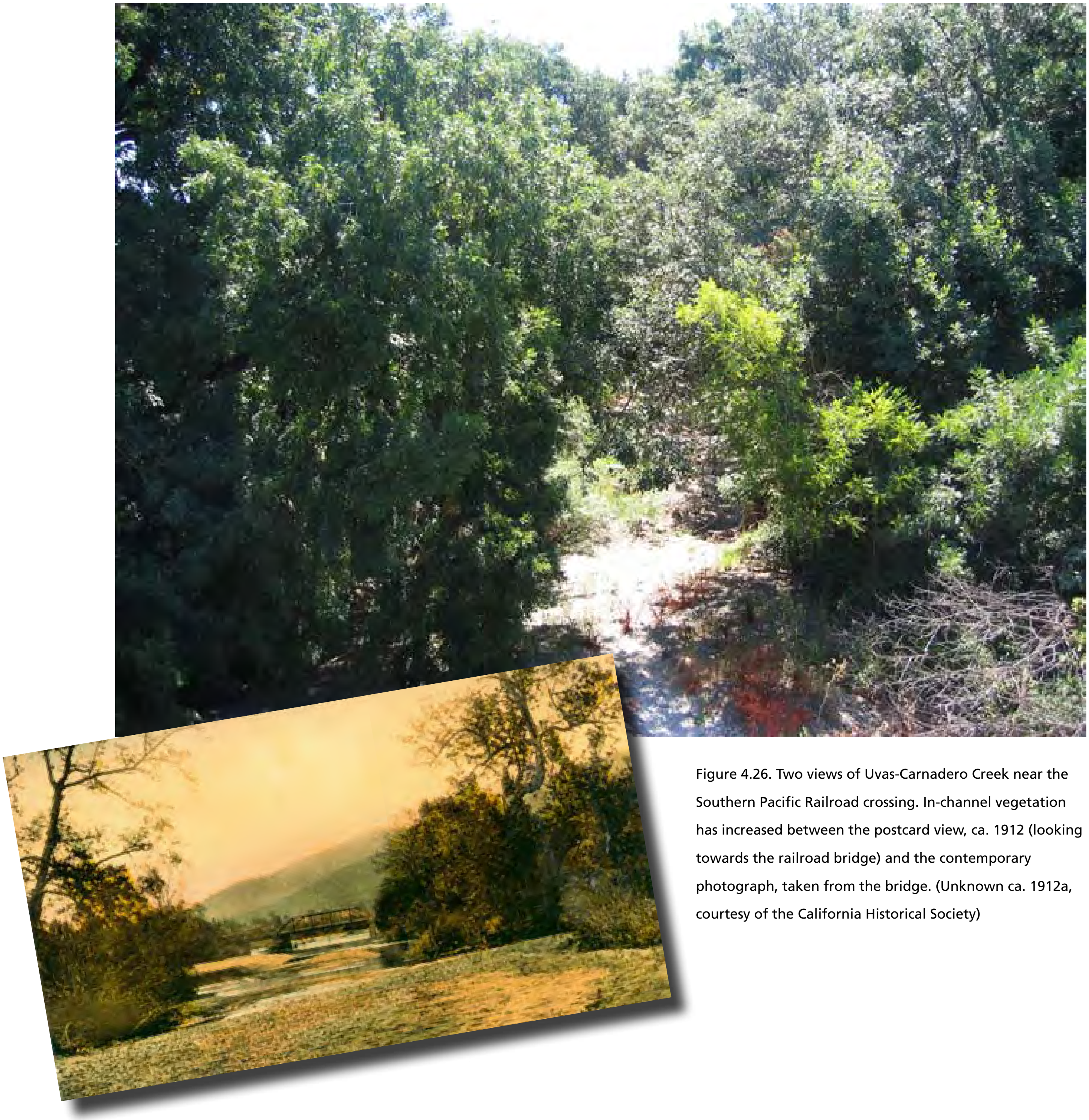


Figure 4.26. Two views of Uvas-Carnadero Creek near the Southern Pacific Railroad crossing. In-channel vegetation has increased between the postcard view, ca. 1912 (looking towards the railroad bridge) and the contemporary photograph, taken from the bridge. (Unknown ca. 1912a, courtesy of the California Historical Society)

floodplain sloughs were typically found adjacent to other lowland wetland habitats such as ponds, lakes and lagoons that also supported lowland fish assemblages, and therefore the movement of fish between slough and ponds was likely. Probable fish species associated with perennial floodplain sloughs include Sacramento blackfish, hitch, thicktail chub, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin, Sacramento perch, and tule perch. Similar fishes comprised assemblages historically in lowland slough and lake environments of the Central Valley and San Francisco Bay estuary watersheds (Gobalet and Fenenga 1993, Moyle 2002, Leidy 2007).

Steelhead adults and smolts likely used floodplain sloughs as migratory pathways. The significance of floodplain sloughs for steelhead rearing within the Pajaro River watershed is unknown. Steelhead are known to rear on the floodplain of the Cosumnes River, a low elevation, perennial stream in the Central Valley (Moyle pers. comm.). Under some conditions, it is probable that as floodwaters receded steelhead could be trapped in sloughs isolated from other waters. However, studies of the Cosumnes River floodplain have shown stranding of native fishes to be minimal, and outweighed by the benefits of floodplain use (Moyle et al. 2007).

Large tributary creeks (perennial mainstem)

Large perennial tributary creeks were probably more expansive prior to extensive diversion and extraction of surface and groundwater resources. Perennial reaches historically found on Uvas and Pacheco creeks supported fishes such as Pacific lamprey, hitch, California roach, Sacramento pikeminnow, Sacramento sucker, rainbow trout/steelhead, threespine stickleback, prickly sculpin, and riffle sculpin (Snyder 1912, CASICD 2008). Historically, mainstem perennial tributary creeks were critically important environments for spawning and rearing steelhead. Smith (2007a) identifies Uvas Creek as currently supporting steelhead downstream of Uvas Reservoir, and it is likely that prior to extensive water extraction practices and reservoir construction perennial mainstem reaches of Uvas Creek were important for steelhead spawning and rearing. These streams also served as migration pathways between perennial headwater streams and the Pajaro River.

Large tributary creeks (intermittent mainstem)

Llagas and Pacheco creeks contained intermittent reaches characterized by alluvial soils that were often completely dry by summer. However, there are historical accounts that intermittent tributary creeks maintained perennial pools embedded in otherwise summer-dry stream reaches, and these pools supported fish such as Pacific lamprey, Sacramento sucker, and steelhead (Wise 1850, Harrington 1929). Permanent pools maintained by subsurface flow that supported fishes were known to occur on Uvas, Llagas (as well as a tributary to Llagas Creek), and lower Pacheco creeks (Wise 1850, Harrington 1929, Williams 1968a,b, Milliken n.d.). Other fishes likely associated with large intermittent tributary creeks such as mainstem reaches of Pacheco and Llagas creeks include Pacific lamprey (migration corridor), hitch, California roach, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, and prickly sculpin (CAS 19080, 13249, 13259, 13247, 13262, 13258 (see Appendix 2); Smith 1998).

Steelhead adults and smolts likely utilized intermittent, low- to mid-elevation reaches of Pacheco and Llagas creeks primarily as a migration corridor (Smith 2007b). On some tributaries, perennial pools fed by groundwater may have provided suitable rearing habitat for steelhead but the historical significance of these habitats to overall steelhead production is unknown.

Small tributary creeks (perennial-to-intermittent headwater)

Small tributary creeks were typically well shaded, and maintained permanent flows with cool summer water temperatures (fig. 7.6). These creeks were characterized by fish assemblages similar to headwater streams in the San Francisco Bay estuary (Leidy 2007). Fishes that utilized these creeks included Pacific lamprey, California roach, speckled dace, Sacramento sucker, steelhead/rainbow trout, threespine stickleback, and riffle sculpin (Snyder 1912, Smith 1982, 2007a, CASICD 2008). Historically, small perennial and intermittent tributary creeks provided significant habitats for spawning and rearing steelhead. Smith (2007a) identifies Bodfish and Little Arthur creeks, Uvas Creek upstream of Uvas Reservoir, and the headwaters of Llagas Creek as currently supporting significant spawning and rearing habitat for steelhead/rainbow trout.

In the absence of water extraction and the migration barriers formed by Uvas and Chesbro reservoirs, these small tributary creeks were presumably some of the most important steelhead streams in the Pajaro River system.

DISCUSSION

South Valley streams and their associated aquatic and riparian habitats have undergone dramatic changes in the past 250 years, many of which have not been well recognized. The drainage network has expanded through the construction of both above-ground channels and underground storm drain systems. Braided channels have been constricted by levees and reclamation. Many reaches have been reengineered for flood conveyance, from simple bulldozing and excavation to complex modern flood channels. Where semi-natural channels remain, the historical riparian canopy of scattered sycamore trees has commonly been transformed into a denser woodland or forest with a mixed composition of native and non-native trees (fig. 4.27). The construction of major dams between 1939 and 1958 bisected stream corridors and altered stream processes.

Since that time, the ability to manage stream flows has further affected stream conditions. Numerous smaller scale impacts such as in-stream barriers, bank alteration, stream diversions, pollution, and other effects have further affected local conditions.

Since many changes have happened in relatively recent decades, these trends are still in progress and choices remain to be made. Information about historical changes can provide context for adaptive management decisions within a dynamic, changing system. Some of these ongoing management activities include flood protection projects, stream restoration efforts, and management of stream flows through reservoir releases.

Expansion of the drainage network

The creation of new channels and the extension of previously discontinuous stream channels has reduced seasonal flooding in South Valley, allowing the expansion of agriculture and cities. The expanded drainage network effectively delivers water to the mainstem channels that otherwise would spread over the valley floor and percolate into the groundwater, or gradually evaporate as seasonal wetlands. As in many other parts of California, continued hydromodification as residential areas expand may increase peak flows and affect the ability of downstream channels to contain them. The historical trend of increasing drainage density could continue to intensify within southern Santa Clara Valley, as above-ground channels and storm drain systems are installed to facilitate urban expansion. These trajectories should be considered with regard to the downstream effect on flood peaks, bank erosion, and other stream functions. Identifying opportunities to enhance on-site retention and percolation can counteract this trend.

Braided vs. single thread channel morphology

Braided channels are typical of streams of the Central California Coast ranges, characterized by highly episodic flows with high sand and gravel loads (Kondolf et al. 2001). These streams typically have a relatively open riparian canopy, often consisting of scattered sycamore trees, riparian scrub, and large, unvegetated gravel bars and channel beds (Keeler-Wolf et al. 1996, Grossinger et al. 2007a). However, the natural processes and ecological values of these systems have often not been well recognized in contemporary stream planning (Kondolf 2006).

In south Santa Clara Valley, broad braided channels dominated the alluvial reaches of most of the major streams. The spatial transition between braided channel and single thread morphology was typically quite distinct and stable through historical time (fig. 4.28). For example, Llagas, Uvas-Carnadero, and Pacheco creeks each naturally became narrower, more sinuous, and more densely wooded in their lowest several miles before spreading into marshes and willow groves. These sudden shifts in channel morphology presumably reflect basic

Figure 4.27. The well-documented Hecker Pass crossing gives a good overview of historical stream characteristics and change. Hecker Pass Road (Highway 152 West) crosses Uvas-Carnadero Creek at the Bodfish Creek confluence, near Gilroy (formerly Bonfante) Gardens. Views from 1876 (A), 1884 (B), and 1939 (C) show how the creek naturally split into two channels around a large bar, crossed by the "Twin Bridges." In recent decades the braided channel has been narrowed, presumably by excavation and filling. This is particularly noticeable at the crossing, where the bridge now follows a more perpendicular route across a smaller channel (D). Trees at (a) can be seen in the 1894 landscape photograph in fig. 4.29. The viewpoints of this image and modern re-photographs are shown at (b). (A: Thompson and West 1876, courtesy of the David Rumsey Map Collection; B: Herrmann Bros. 1884, courtesy of the Office of the Santa Clara County Surveyor; C: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; D: USDA 2005, courtesy of NAIP)

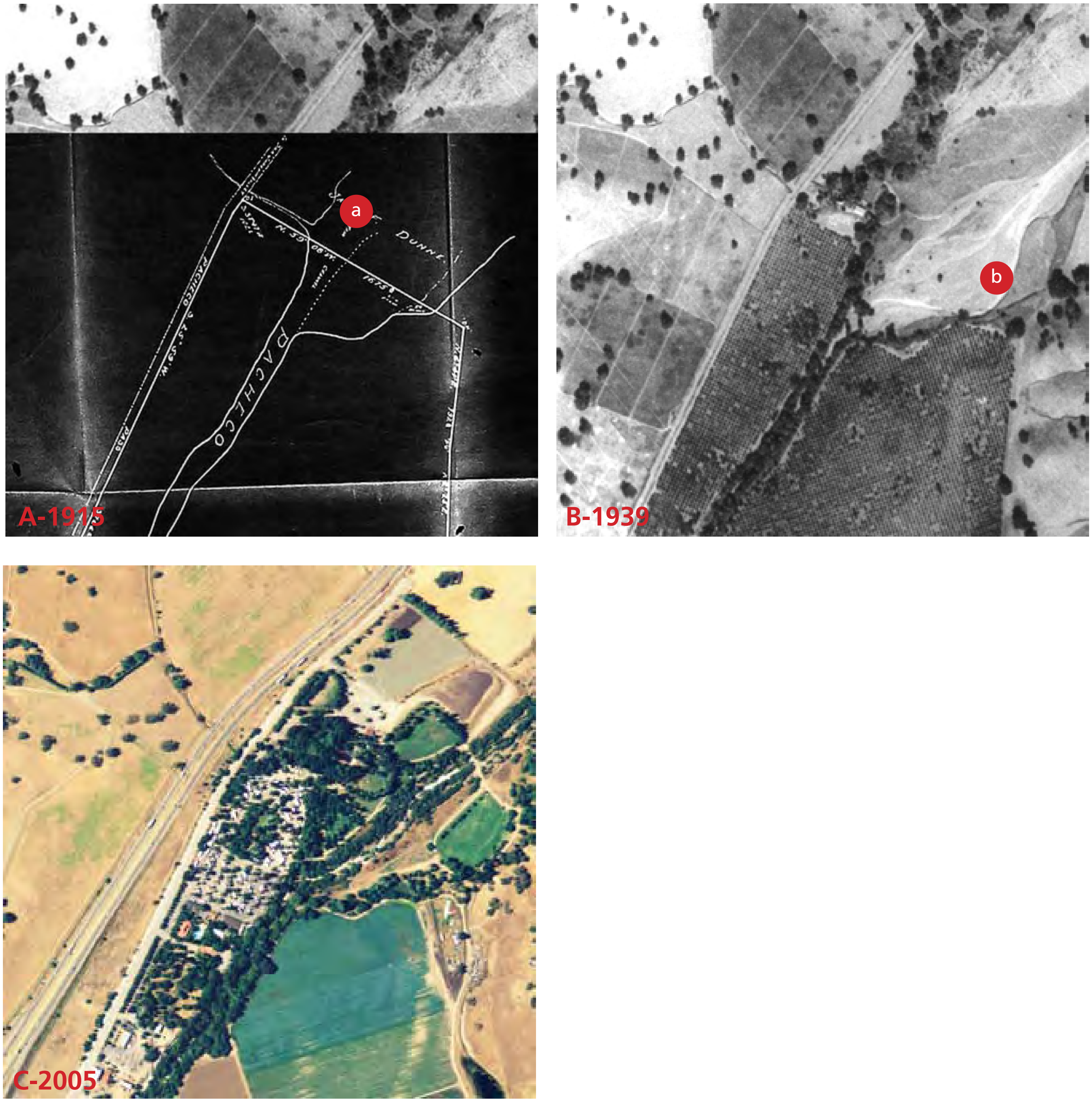


Figure 4.28. Transition from braided to single thread meandering channel on lower Pacheco Creek. The shift in morphology is shown in the exact same location by Winn (1915; A) as in 1939 aerial photography (B), although the main channel (a) moved from the west to the east (b). Most of the adjacent bars and terraces have been occupied by development by 2005 (C). (A: Winn 1915, courtesy of San Benito County Public Works; B: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; C: USDA 2005, courtesy of NAIP)

changes in channel gradient, stream power, sediment load, and dry season flow.

Despite this local prevalence, stream restoration efforts have not necessarily recognized this natural stream form. For example a 0.9 km (0.5 mi) reach of Uvas-Carnadero Creek that was historically a braided channel was reengineered in 1995 to be a sinuous, meandering channel as part of a stream restoration project (City of Gilroy 1998). During the first winter, the constructed channel was overwhelmed with sediment and reestablished a braided morphology (Kondolf et al. 2001). The lack of understanding of historical geomorphic processes resulted in an unsuccessful design.

Similarly, while the EIS/R for the Llagas Creek Watershed Project (USDA 1982) evaluated environmental impacts of the previous channel excavation, discussion of mitigation focused heavily on impacts to the fairly anomalous highly sinuous reach (near Leavesley Road), with little or no mention of braided channel or sycamore alluvial woodland characteristics.

While gradual conversion to narrower, more densely wooded channels continues to take place through flood control, excavation of low flow channels, and altered water regimes, braided channel processes appear to be at least somewhat intact. Despite the construction of dams on Uvas and Pacheco creeks, significant portions of their watersheds remain unregulated and evidence suggests that in places (e.g., fig. 4.22; Kondolf et al. 2001) these channels have continued to behave as high energy braided systems with dynamic low flow channel and bar positions. However, channel narrowing is likely to continue as artificial dry season stream flows allow riparian vegetation to encroach on lateral bars.

One of the effects of riparian encroachment is increased water surface shading, which lowers local water temperatures and may reduce food production and growth rates for fishes. Smith (2007a) notes that riparian shading of Uvas Creek upstream from Highway 152 may lower water temperatures and interfere with the ability of steelhead to feed on drifting insects. In addition, steelhead densities appear higher in sunlit riffles. Smith (1982) also noted that the fast growth of steelhead in the productive, sunlit (warmer), fast-water reaches of Uvas Creek allowed fish to smolt after one year compared to cooler shaded tributaries. Historically, mainstem Uvas Creek had a more open riparian canopy (e.g., figs. 4.26 and 4.29). Perennial pools, if present, would likely have produced faster growing and larger smolts better able to survive outmigration and ocean conditions.

Braided channels with frequently shifting low flow channels, occasional groundwater-fed pools, and associated open canopy riparian habitat may be appropriate goals for restoration and enhancement in some places within south Santa Clara Valley. As suggested by the experience on Uvas Creek, such targets might be appropriate for certain stream reaches because (1) they are morphologically appropriate to local stream processes and (2) they offer a different suite of ecological and aesthetic attributes. The dynamics of channel migration, bed scour, and bank erosion which are responsible for creating much of the habitat value of streams – including undercut banks, clean gravels, and persistent pools (e.g., Ward and Stanford 1995) – may be reduced by accidental or intentional conversion of these systems to a different morphology and ecology (Kondolf et al. 2001; figs. 4.28 and 4.29). Sites where sufficient width, sediment supply, and hydrologic regime still exist to maintain braided channel dynamics should be identified and considered as part of local stream restoration targets.

The Uvas Creek restoration project is apparently considered to have been a failure of stream restoration, although the reestablishment of a braided channel could be considered a restoration of natural conditions at the site (Eischeid ca. 2001.). This is presumably because of a common cultural perception that streams should be sinuous, well defined, and lushly wooded (Kondolf 2006). These examples suggest that greater public awareness of the natural heritage of the region – how streams naturally look and function in the region – may be important for successful local stewardship.

Sycamore alluvial woodland on Pacheco Creek

The braided, sycamore alluvial woodland reaches of Pacheco Creek constitute a regionally unique habitat that has survived to the present day, but its persistence in the future may be threatened. Sycamore alluvial woodland is recognized as a rare community within the state of California, with Pacheco Creek retaining one of the 17 significant remaining sites of Central California Sycamore Alluvial Woodland (CCSAW; Keeler-Wolf et al. 1996). Opportunities for conservation and restoration are particularly rare for this community because of its relatively restricted natural distribution and heavy impact from modern development (Keeler-Wolf et al. 1996). Accordingly, the Independent Science Advisors for the Santa Clara Valley HCP/NCCP have emphasized the importance of designing reserves within the region for the habitat (Spencer et al. 2006).

In a statewide assessment (Keeler-Wolf et al. 1996), the five-mile Pacheco Creek sycamore alluvial woodland (figs. 4.30 and 4.31) was found to be one of the most important of the 17 surviving remnants. At the time of the study, Pacheco Creek was the sixth largest instance of CCSAW in the state, and the second largest outside of the Central Valley. Two different ranking approaches were developed to evaluate the quality of each stand, considering factors such as size, fragmentation, hydrology, and other human impacts. Pacheco Creek was ranked sixth and eighth within the state according to this evaluation. Within the San Francisco Bay-Monterey Bay area, it was judged to be either the first or third most important site, depending upon the ranking criteria. (Alameda Creek supports the other highest ranking local remnants.) Sycamores here are in the northern part of their range; however, that range might be expected to expand northward given climate change predictions (Kueppers et al. 2005; CCCC 2006).

The Pacheco Creek sycamore stands are hindered by the alteration of natural hydrologic processes by North Fork Pacheco Reservoir and gravel mining excavations, as well as grazing pressure (Keeler-Wolf et al. 1996). The widening of Highway 152 caused the removal of some stands and the confinement of the stream under two bridge crossings. Some significant loss of trees can be observed in some areas since 1939 (fig. 4.32). Reproduction within the stands appears to be limited, so their long-term future is not assured (Keeler-Wolf et al. 1996). It is likely that the construction of Pacheco Dam in 1939 has limited the natural flooding, scouring, and sediment deposition on Pacheco Creek alluvial bars and terraces, affecting the conditions that support sycamore regeneration. The capture of sediment behind Pacheco Dam has also likely produced sediment-starved water, which can cause the mainstem channel to incise, further reducing flooding of adjacent floodplain surfaces.

In addition, the release of stored water during the dry season for groundwater recharge and agricultural use appears to be gradually causing riparian conversion similar to that observed on other local streams. Comparison of 1939, 1963, and 2005 aerial photographs shows the development of new riparian vegetation along the low flow channel in recent decades, (figs. 4.32 and 4.22). Armoring of the low flow channel is a common response downstream of dams, which commonly leads to channel down-cutting and abandonment of the floodplain (Kondolf and Downs 1996, Cloak and Buchan 2001).

Channel invasion by more hydrophilic species is facilitated by the lack of natural scouring flows resulting from the attenuation of flood peaks within the reservoir. However, this effect can also occur simply as the result of increased summer water discharges to a formerly intermittent stream (White and Greer 2006). Comparison of Pacheco Creek to the only sycamore alluvial woodland in the vicinity that remains unimpacted by water regulation – the much smaller Coyote Creek stand upstream of Coyote Lake – illustrates similar differences as the temporal 1939-2005

Figure 4.29. Renowned local painter/photographer Andrew P. Hill probably took the 1894 picture looking upstream from a gravel bar on Uvas Creek, titled “Twin Bridges from creek bed — 1894” (B). The image shows the large mid-channel sand and gravel bar, two main channels, and pair of bridges (illustrated in fig. 4.28). Several sycamores and other riparian trees, and large freshly scoured gravel surfaces, can be seen. (A horse and carriage heading west from the bridge are obscured by the tree on the right.) Precise re-occupation of the site is difficult because of the great expansion of vegetation in the channel

in the century since the photograph was taken (A), and also in the decade since (C). In addition, the right-hand margin of the channel has been filled (as part of modern bridge construction) so the original creek bed location of the photographer is now dry landfill. In concert with fig. 4.28, this unusually well-documented location illustrates the common trajectory of braided streams within the region, including channel narrowing, loss of fresh gravel surfaces, and riparian habitat conversion (A: courtesy of Matt Kondolf; B: Unknown 1894a, courtesy of Matt Kondolf and the Gilroy Museum).

Figure 4.30. California sycamores along Pacheco Creek are particularly distinct in this Google Earth image. While the deciduous sycamores are in fall color, evergreen live oaks on the hillsides remain green. (Courtesy of Google)

Figure 4.31. The relationship between sycamores and low-elevation, frequently scoured channel surfaces can be seen on Pacheco Creek just downstream from the North Fork Pacheco Reservoir.

Figure 4.32. Several changes can be observed in these images of sycamore alluvial woodland on Pacheco Creek along Highway 152. In the contemporary image (B), there are fewer sycamores, less evidence for active side channels and floodplain scouring, and more riparian growth immediately along the low flow channel than in the historical image (A). (A: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B: USDA 2005, courtesy of NAIP)

comparison. At upper Coyote Creek, the low flow channel is broad and very shallowly defined with almost no vegetation (as seen in Google Earth). The absence of any stands of riparian vegetation on the banks of the low flow channel is particularly evident.

Despite these observations, there are some factors, in addition to their regionally unusual size, that suggest there remains significant conservation potential for the Pacheco Creek sycamore alluvial woodlands. While the North and Middle forks flow into Pacheco Lake, the South Fork (which represents a significant portion of the watershed above the sycamore reach) and other smaller tributaries remain unregulated. In addition, it is possible that management of regulated flow regimes from North Fork Pacheco Reservoir could be adjusted to more closely mimic natural regimes for the benefit of the sycamore woodlands.

Sycamore restoration and preservation efforts should be based upon an evaluation of whether the long-term maintenance of sycamore woodlands is a priority and, if so, the development of a management plan with riparian ecologists, biologists, geomorphologists, and water managers. Relative benefits of different flow regimes and sediment storage/transport processes should be considered with regard to target fish, amphibian, bird, and riparian plant communities.

North Fork Pacheco Reservoir management

Several management options could be considered to improve the effect of North Fork Pacheco Reservoir on native fishes and riparian functions. Removal of the reservoir is unlikely because of its water supply functions. However, decommissioning could have a dramatic positive benefit for both these sycamore alluvial woodlands and steelhead, presuming that significant spawning habitat would be accessible upstream of the dam.

With the reservoir in place, water management strategies could still have significant benefits. One option to consider is annual summer drawdown, which could control the establishment of non-native fish populations in the reservoir. This could reduce the negative effects of introduced species on steelhead and other native fishes.

A number of studies of California sycamore have shown that disturbance by flooding is the most likely approach to support successful stand-expanding sexual reproduction, as well as vegetative reproduction through sprouting (Keeler-Wolf et al. 1996). For the preservation and maintenance of braided channel characteristics and sycamore alluvial woodlands, factors to consider would be whether it would be possible with current infrastructure or infrastructure modifications (e.g., flap gate retrofits, strategic downstream levees) to produce geomorphically effective high-flow pulse releases, while meeting flood protection and water supply objectives. Approaches to reactivate bars and associated ecological and geomorphic benefits on other regulated streams could be considered. These include the timing of pulse releases with the natural input of sediment from unregulated tributary streams to maximize sediment redistribution (USGS 2007), and the "notching" of starter side channels into currently inactive bars and terraces (Ligon et al. 1995).

Well-timed reservoir releases could also potentially improve the chances for sycamore seed germination by providing moist ground for successful establishment. On intermittent stream channels with highly episodic flows, these conditions require fortuitous timing with late-season storms and as result are not very reliable, particularly in the northern part of their range. Coordinating the timing of late spring/early summer water releases with the phenology of sycamore seed production could potentially improve the reproductive success and long-term survival of the Pacheco Creek sycamore stands (Keeler-Wolf pers. comm.). This would involve field observation of the actual timing of seed release in a given year and calibration of flows to moisten, but not scour, channel surfaces. These releases could also potentially benefit outmigrant juvenile steelhead on Pacheco Creek (Smith 2007a).

Large mid- and late-summer reservoir releases are likely to cause negative effects on the Pacheco Creek sycamores, as the species prefers gradual drawdown of the water table through the summer and roots can be injured by a higher water summer table (Keeler-Wolf et al. 1996). Presently, North Fork Pacheco Reservoir is operated to release water at these times to recharge groundwater for use by downstream farmers, which has probably contributed to the changes observed in recent decades. It is possible that releases could be delivered more gradually, allowing flow to remain subsurface and more closely mimicking the natural patterns of an intermittent stream, while reducing negative effects on the sycamore alluvial woodlands. However, there is also rationale for increasing dry season surface flows for the benefit of steelhead (Smith 2007a).

Sycamore restoration on other streams

In addition to the more prominent sycamore woodland reaches, more dispersed sycamore habitat along braided channels was also a dominant feature of South Valley streams, especially Llagas Creek. This element of the local landscape was celebrated in souvenir postcards, photographs in guidebooks, and written descriptions. Little or none of this habitat currently exists, except for remnant trees alongside flood control channels (fig. 4.33). However, sycamores could be reintroduced as part of channel redesign projects incorporating natural flood protection principles. California's sycamore could be planted as a riparian tree on natural or excavated floodplain benches and banks. Uvas and Llagas creeks still maintain many isolated sycamore trees on former bars and terraces. Former benches could be reconnected, as they were for the Llagas Creek "oxbows" (USDA 1982).

Similar consideration of stream flow management regarding timing of seed set, extent of summer water, and pulse winter flows as discussed earlier would benefit these riparian restoration efforts where possible, reconnecting braided channels to parts of their floodplain could benefit other stream functions, such as sediment

Figure 4.33. Llagas Creek between Highway 101 and Pacheco Pass Road is a narrow, excavated channel that nevertheless mostly follows its historical course. As a result, mature California sycamores and other riparian trees are frequently found alongside the channel on former bars, terraces, and banks of the historical channel. This pattern can be seen here near the Church Street percolation ponds. Eucalyptus trees are a common component of the new channel banks, dominant in places. A remnant tree of the adjacent valley oak savanna can be seen on the right.

redistribution and channel capacity (fig. 4.34). On streams where potential steelhead support functions are currently highly limited, such as Llagas Creek downstream of 101 (Smith 2007a), such efforts could return some elements of native habitat function to the present engineered channel.

Pulse flows

In addition to helping maintain some of the surviving sycamore alluvial woodlands, controlled yet significant high-flow pulse releases could help maintain or restore downstream habitat quality and improve native fish populations. Local research suggests that native fish are better adapted to the short-duration, high-flow events characteristic of historical conditions than their non-native competitors (Buchan and Randall 2003). Significant, well-timed late winter/early spring releases have been designed to mimic natural flood processes in other watersheds (e.g., Kondolf 1998, USGS 2007) and could potentially improve habitat for a range of native fish on local streams. Pulse flows could also remove short-lived woody vegetation that has expanded into the former active channel in some areas since reservoir construction, reducing trash jams and increasing channel capacity.

Intermittent stream values

Intermittent stream reaches were prevalent historically on the valley floor, but are increasingly prioritized for conversion to perennial flow using imported and/or stored water supplies. While there is strong rationale for such efforts, notably the support of steelhead, it is important to recognize some of the values of intermittent streams with permanent pools for native flora and fauna.

Natural summer drawdown of streams to persistent pools can favor native fish over most non-natives. Historically, intermittent stream reaches with persistent cold water pools fed by subsurface flow supported robust native fish assemblages, including Sacramento sucker and steelhead (Harrington 1929). Some of the healthiest present-day native fish communities on Santa Clara County streams are observed in reaches with similar summer dry back (Buchan and Randall 2003, Stern pers. comm.). Recent research on San Francisquito Creek also suggests the value of persistent pools connected by subsurface flow, which tend to remain cooler than areas with surface flow (Weiss pers. comm.). If such conditions can be successfully achieved, they may reduce the susceptibility of invasion by non-native fish species while benefiting native fish and riparian communities.

Similarly, certain native bird species were adapted to these environments. For example, lesser nighthawks (*Chordeiles acutipennis*) nested on South Valley streams into the 1930s, breeding in the broad, gravelly, summer-dry channel beds of braided creeks. Accordingly, the species was consistently recorded on braided reaches of Coyote Creek and Uvas-Carnadero Creek near Gilroy (Pickwell and Smith 1938, Bousman 2007), but no longer breeds locally. Like sycamore alluvial woodlands, lesser nighthawk in Santa Clara County are near the northern margin of their historical range. However, with anticipated climate change they may become increasingly relevant to local conservation planning.

Riparian tree species associated with intermittent streams, such as sycamores, live oaks, and valley oaks, are also more tolerant of drought conditions than the hydrophilic species supported by perennial reaches. These riparian systems are well adapted to xeric conditions and, compared to species dependent upon imported water, would be expected to be more likely to survive extended drought conditions and/or water shortages that can be anticipated in the future.

Designing stream flows to support stream and riparian choices

The creation of large reservoirs on the major streams of south Santa Clara Valley has created a new mosaic of habitats and species assemblages responding and adjusting to reservoir management operations. Summer releases designed for groundwater recharge and steelhead habitat have increased the downstream extent of perennial surface flow by as much as several miles in some years. The attenuation of winter floods has reduced the height of peak flows and the associated scouring effects on channels downstream. The change in the annual hydrograph has caused riparian vegetation to invade many of the formerly open gravel bars and stream benches of South Valley streams. Cottonwoods, willows, arundo and other riparian plants have expanded their distribution within these systems. Similarly, fish species such as hitch have apparently been able to expand their distribution in response to these conditions (Smith 1982). Local investigations indicate that these practices have increased successful steelhead rearing and outmigration, at least in places (Smith 2007a).

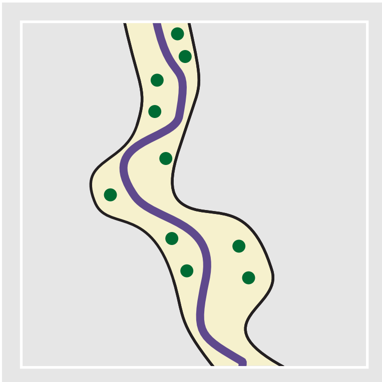
At the same time, historical trends suggest these practices may have unintended long-term effects on the system. Increased in-channel vegetation reduces channel capacity and may limit the benefit of summer pools for drift feeding juvenile steelhead smolts (Smith 2007a). In the absence of high flow releases, the elimination of natural channel maintenance processes such as scouring and gravel redistribution may decrease the value of in-stream aquatic habitats for steelhead and other native fish over time. Peak flow reduction and dry season flow increases on Pacheco Creek are likely to convert the channel over time into an incised, single thread channel isolated from its floodplain, along with gradual elimination of the sycamore alluvial woodland stands.

Given the challenge of supporting these various and sometimes competing natural resource objectives in the future, probable long-term system trajectories and design options should be considered by a multidisciplinary group with expertise in fish ecology, riparian ecology, fluvial geomorphology, and water management. Stream reaches can be prioritized for target functions to maximize the maintenance of local ecological resources, the benefits of imported water supplies, and the resilience to climate change. A spatially explicit mosaic of riparian and aquatic targets that considers persistent habitat controls, current conditions, and long-term trajectories can provide a framework for sustainable watershed management.

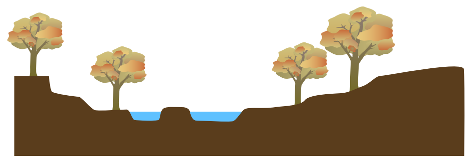
Landscape trajectories

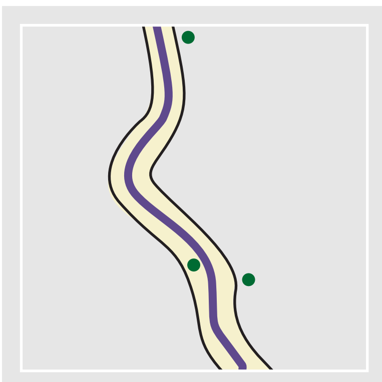
South Valley riparian habitats were modified relatively recently, compared to other local habitats such as oak savanna, freshwater marsh, and willow groves. While the latter were mostly eliminated by World War II, the historical record suggests that general riparian patterns did not change dramatically until after the 1950s, with the construction of large reservoirs and flood control channels. As a result, some local residents can still recollect relatively "pristine" conditions on local streams.

The effects of these large, post-World War II constructions are particularly wide ranging. However, the slower development of flood control efforts in the area means that significant projects, such as along the Llagas, are still underway, with the potential for incorporating riparian habitat and natural flood protection strategies (fig. 4.34). In addition, while many stream reaches have been heavily modified in the past half-century, some have experienced much less change. As a result, streams such as Pacheco Creek, and parts of Uvas Creek, are still in the process of responding to altered hydrologic regimes associated with stream regulation. At the present moment, these systems are relatively early in their trajectory of change, presenting opportunities for adjusting those trajectories through adjustments in environmental management.

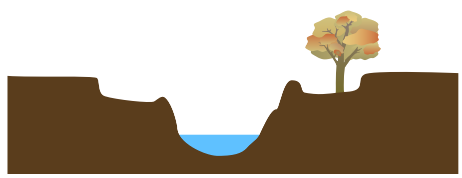


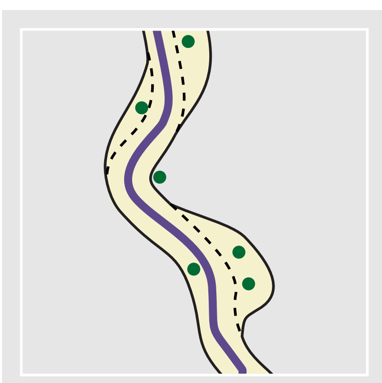
ca. 1800: Scattered California sycamores occupy banks, bars, and terraces along braided channels.





2008: Flood control channels disconnected the channel from the adjacent bars and terraces. A few isolated trees remain outside the levees.





Conceptual restoration model: Floodplain surfaces could be strategically reconnected to the channel.

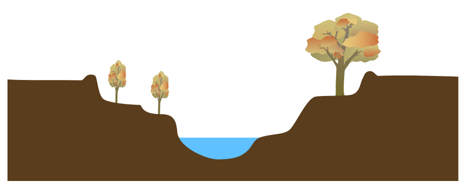


Figure 4.34. Braided stream channels with open sycamore canopy: conceptual model of landscape trajectory

5 WETLAND HABITATS

Above. Flooded intersection of Frazier Lake Rd. and Bloomfield Ave., 1952. *Below.* Northern San Felipe Lake.

WETLAND HABITATS

In a semi-arid region such as south Santa Clara Valley, wetlands tend to be relatively uncommon and ecologically significant. Accordingly, perennial and seasonal wetlands serve as essential habitat for a number of special status species, such as the California tiger salamander *(Ambystoma californiense)*, California red-legged frog *(Rana aurora draytonii)*, southern Pacific pond turtle *(Actinemys marmorata pallida)*, and tricolored blackbird *(Agelaius tricolor),* and are important to migrant and resident shorebirds and waterfowl. Permanent surface waters within perennial wetlands can be particularly important as year-round sources of water for a variety of wildlife. Wetlands can also perform important hydrogeomorphic functions, including the attenuation of flood peaks by temporarily storing surface waters and the storage of fine sediment carried by streams. Because of their widely recognized value, there is significant interest in the potential for local wetland conservation and restoration (Jones and Stokes 2006, SCVWD 2006a,b). This interest has led to questions about the historical extent of wetlands, the distribution and abundance of different wetland types, and the potential for the recovery of wetland resources. To address these questions, we documented the range of native wetland habitat types that occurred within the study area prior to significant Euro-American modification.

METHODS

We used several strategies to identify historical wetlands of different kinds. First we determined the major types of wetlands historically common to the study area, including valley freshwater marsh, open water ponds and lakes, intermittent lakes/playas, and wet/alkali meadows. A fourth type – willow groves – could also be considered riparian habitat, but is discussed here because it is more closely associated with the other wetland types.

Valley freshwater marsh refers to persistent emergent freshwater wetlands typically dominated by bullrushes *(Scirpus* sp.*)*, cattails (*Typhas* sp.), sedges (*Carex* sp.), and rushes (*Juncus* sp.). These wetlands are seasonally flooded (Cowardin 1979); soils generally have a high organic content and are usually saturated. Perennial ponds are permanently flooded, unvegetated areas, typically within larger surrounding marshes.

Wet meadows are temporarily to seasonally flooded grasslands characterized by poorly drained, clay-rich soils. Alkali meadows, or alkaline grasslands, are characterized by fine-grained soils that have a high residual salt content supporting a distinctive, salt tolerant plant community, including some species characteristic of salt marshes or vernal pools/swales (Baye et al. 1999, Holstein 1999). Soils of the wet and alkali meadows can remain moist for much of the year (e.g., “Moist Grassland”; Goals Project 1999). Playas are intermittently flooded lakes characterized by unvegetated, alkali-affected clay substrate. Willow groves are forested wetlands dominated by *Salix lasiolepis* (Cooper 1926) that are distinct from the narrower strands of willow riparian forest commonly found along streams. These features are often associated with groundwater emergence (Collins and Grossinger 2004).

Perennial ponds, large playas, freshwater marshes, and willow groves were important landmarks in 19th-century south Santa Clara Valley and thus were clearly identified by many early maps. Cartographic evidence was often also confirmed by historical textual accounts. Characteristic wetland signatures in early aerial photography (dark, mottled patterns) often corresponded with earlier historical evidence. Where earlier evidence was incomplete, early aerial photography was occasionally used to refine historical habitat boundaries. It is likely that we were able to document most of the relatively large features, accounting for most of the area of these perennial wetlands, but many smaller features that occurred historically are likely not revealed through this process.

Perhaps due to their broad, more diffuse character, habitats such as wet meadows and alkali meadows did not serve as important historical landmarks and are not explicitly indicated on most early maps. However, historical and contemporary soil surveys carefully assess the soil and drainage characteristics associated with these habitat types because of their limiting effects on agriculture, producing effective maps of these significant components of the landscape. Applying equivalent criteria used in earlier mapping efforts in north Santa Clara Valley, we evaluated the hydrogeomorphic characteristics of historical and modern soil types in south Santa Clara Valley to identify wet meadow and alkali meadow areas (Grossinger et al. 2006, 2007a). Some descriptive evidence from 19th-century surveys and maps was found to corroborate these areas, as well as early aerial imagery. Wet meadows were divided into three classes based on the degree of soluble salts affecting plant community composition (i.e., alkali effects) as described by the soil surveys. Modern soil boundaries published at 1:31,680 scale "should be accurate within at least 100 feet" (USDA 1951), indicating a fairly high level of confidence in soil boundary location. Since we also used earlier soil surveys produced at twice this scale (1:62,500), we classify these boundaries within our medium level of certainty (150 m/500 ft). We adjusted the boundaries of wet/alkali meadow slightly where it conflicted with well-documented oak woodlands.

> *"Soils, then, are landscapes as well as profiles. The soil mapper has always recognized this in drawing soil boundaries. Commonly they come at the foot of an escarpment, at the margin of the swamp forest, or at some other obvious boundary among natural landscapes."*
>
> – USDA 1951

For the Santa Clara County portion of the study area, we were able to use recent land cover mapping by Jones and Stokes (2006) to compare historical and modern spatial extent of several habitat types. Earlier data (based on 1981-82 aerial photography) from the National Wetland Inventory (USFWS 2007) were available for the San Benito County portion of the study area.

RESULTS

Regional spatial patterns

Wetlands, either seasonal or perennial, covered approximately one-third (34%) of the study area prior to agricultural and urban drainage efforts. Of the 9,000 ha (22,000 ac) of wetlands, most (83%) were seasonal wetlands. The seasonal wetlands were almost evenly divided between salt-affected alkali meadows and wet meadows unaffected by salt accumulation: each covered about 3,700 ha (9,000 ac). Willow groves and freshwater marshes were smaller but substantial components of the landscape. Each represented roughly 3% of the study area and covered 700-800 ha (1,700-2,100 ac). There were at least 64 ha (158 ac) of perennial freshwater ponds.

Wetlands of different types occurred in distinct landscape positions, resulting in their heterogeneous geographic distribution. At the largest scale, wetlands were typically located in the nearly flat or basin-like lowlands at the foot of, or in between, alluvial fans and natural stream levees. In south Santa Clara Valley, where the major drainages flow roughly south, this led to a general pattern of dry oak lands and grasslands in the north, and large wetlands in the south. Accordingly, almost all of the perennial freshwater marshes, ponds, and willow groves were located south of Highway 152/Pacheco Pass Road. (This is not a coincidence, as the road alignment was likely chosen to avoid overflows.)

Over one-third of the study area consisted of wetlands of one type or another. Most wetland types were found exclusively in the southern part of the study area.

As large streams moved high sediment loads from erosive Franciscan geology down their valleys, they built up natural levees of coarse sediment (Helley and LaJoie 1979). These high spots were overtopped by flood flows, carrying finer sediment into adjacent bottomlands (figs. 5.1 and 5.2). The low areas had little available drainage and often were effectively trapped by their low topographic gradient and/or converging natural "dams" of alluvial levees. Similar patterns have been observed in other regions such as north Santa Clara Valley (Torbert 1936) and Napa Valley (Carpenter and Cosby 1938).

Wetlands formed in this fashion were common in the region, and often had a distinctively linear orientation. Levee-side wetlands included: the narrow strand of wet meadows, ponds, and swales that ran alongside Pacheco Creek, trapped between the Pacheco Creek levee and adjacent hills; and the broad parallel strands of wetlands on either side of the Llagas Creek levee, which reached widths of 1.5 km (1 mi) and extended for several miles. Wet meadows were found in similar valley bottom positions scattered throughout South Valley, and many have continued to be subject to flooding, such as the wet meadows and swales historically along Tennant Creek (USACE 1975).

These patterns of alluvial topography created an area of particularly restricted drainage along the lower end of Llagas Creek, caused by neighboring Carnadero Creek. At Bloomfield Road, the natural levee of Carnadero Creek spread into a broad cone of sediment built from deposition along the different routes the stream has taken in recent geological history. One lobe of this cone extends almost due east for over a mile, effectively blocking drainage from the wetlands alongside and at the base of Llagas Creek (Cosby and Watson 1927a). This slightly higher levee land, now traced by Bloomfield Road, can be seen in both local soils and topography (figs. 5.1 and 5.2).

The largest area of seasonal wetlands occupied the broad Bolsa basin, where the distal ends of each of the major stream levees dissipated into the shared Soap Lake floodplain (SCCFC&WD 1972). These meadowlands were dominated by alkali conditions, resulting from seasonal evaporation of shallow flood waters in these exceptionally flat lands. In south Santa Clara Valley , the alkali meadows dominated, and were limited to, the Bolsa.

While freshwater ponds and marshes are always located on the wet meadow soils, willow groves straddle the boundary between the moist and well-drained soils.

Perennial freshwater marshes, ponds, and willow groves were closely associated with the clay-rich, wet/alkali meadow soils. Freshwater marsh and a few perennial ponds occupied the lowest, wettest portions of the wet meadows, located in depressions and/or associated with springs. While mapped from independent sources, 96% of the valley freshwater marsh area coincided with wet/alkali meadows soils. The coincidence between perennial freshwater ponds and the wet/alkali meadows soils was 100%. Like the wet meadows, valley freshwater marshes were often neatly positioned between the fingers of natural stream levees. Examples include the extensive marshes downstream of Miller Slough (between the Llagas and Uvas-Carnadero natural levees) and the marsh between San Felipe Road and Lovers Lane, between radiating levee strands of Pacheco Creek.

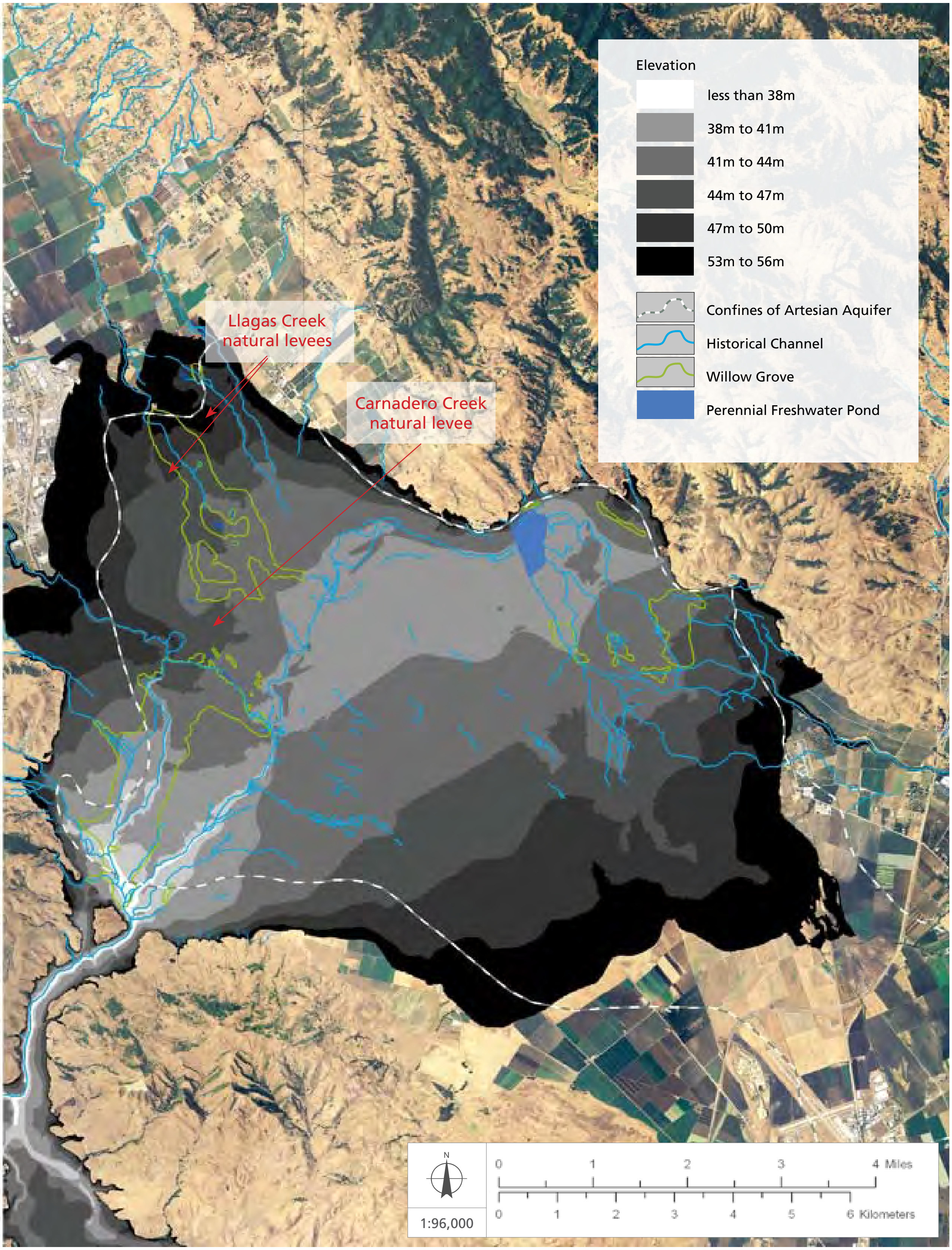


Figure 5.1. This shaded relief map shows the Soap Lake floodplain (lighter grays) and adjacent topography, with an overlay of historical features. Willow groves, shown in green, commonly intercept the historical boundary of artesian conditions (Clark 1924; dashed line). Historical creeks are shown in blue. Natural levees can be seen as higher (darker) ground following historic or pre-historic stream courses. These protrusions create adjacent, bottomland basins. (USDA 2005, courtesy of NAIP)

In contrast, willow groves consistently occupied the interface between the poorly drained wet meadow soils and the adjacent, coarser alluvium. The coincidence between willow grove and wet/alkali meadow soils was 60%, and this interface position was consistent among the three large willow groves at the base of Carnadero, Llagas, and Pacheco creeks (which account for most of total willow grove area). Thus each of the three major willow groves was positioned at the mouth of the stream where it spread into wet meadows. Each grove had 54-66% of its area in the wet meadow soils and the remainder on the adjacent, coarser levee soils.

Not coincidentally, this landscape position also correlates with the outer boundary of the historical artesian zone. Most of the willow groves intercepted the artesian boundary, with most of this area within the artesian zone (fig. 5.1). They occupied a consistent landscape position at the interface of wet/dry soils, artesian conditions, and 40-50 m (130-170 ft) elevation. Willow groves formed at the transition between silt and clay soils, where there was access to reliable water near the surface but soils were not completely waterlogged and anaerobic.

Historically, the South Valley study area had proportionally more wetlands than the Coyote Creek area to the north (Grossinger et al. 2006, Grossinger et al. 2007a). Excluding the baylands portion of the Coyote Creek watershed, the south Santa Clara Valley study area covers a slightly larger area (26,500 ha/65,500 ac vs. 23,000 ha/57,000 ac). Despite covering only 15% more area, the region had 50% more wet meadow, more than twice as much alkali meadow and valley freshwater marsh, three times as much area of perennial freshwater pond, and five times as much willow grove habitat. This high proportion of wetlands, predominantly in the southern part of the study area, suggests the significance of the area for wetland conservation and restoration.

Habitat changes

Based upon the combined Jones and Stokes (2006) and National Wetland Inventory (USFWS 2007) mapping, valley freshwater marsh has declined by about 90% in the study area (672 ha/1,660 ac historical to 66 ha/160 ac modern). The reduction in habitat area is particularly dramatic around San Felipe Lake, recognized as one of the most important remaining wetland habitat areas today. San Felipe Lake, which was historically bordered by over 100 ha (250 ac) of valley freshwater marsh, was mapped in 1981-82 as having only 8 ha (20 ac) of marsh on its margin.

The changes in willow grove habitat are somewhat more complex. We mapped 831 ha (2,050 ac) of willow grove in the study area, historically. Jones and Stokes (2006) recently mapped 307 ac (760 ac) of "willow riparian forest and scrub" in the Santa Clara County portion of the study area. In addition, U.S. Fish and Wildlife Service (2007) mapped almost 10 ha (25 ac) of "freshwater forested/shrub wetland" in the San Benito County portion of the study area. Comparing the historical and modern totals indicates a decline of 62% in willow habitat.

While the area of willow riparian habitat has declined by about 60%, the edge-to-area ratio of the current habitat has increased by over 700%.

However, changes in the shape and distribution of the remaining habitat have probably caused an even greater decline in functional habitat for many species associated with the interior of riparian areas. In contrast to the wide, contiguous areas of historical willow groves, most of the present-day habitat is in the form of narrow linear strips alongside stream channels. Historically, the ratio of habitat perimeter to area was 62 m/ha (80 ft/ac). The perimeter to area ratio for the present-day willow riparian areas is 446 m/ha (600 ft/ac), an increase of over 700%. This increase in edge effect is likely to have greatly reduced the value of the remaining willow habitat for many endemic riparian species.

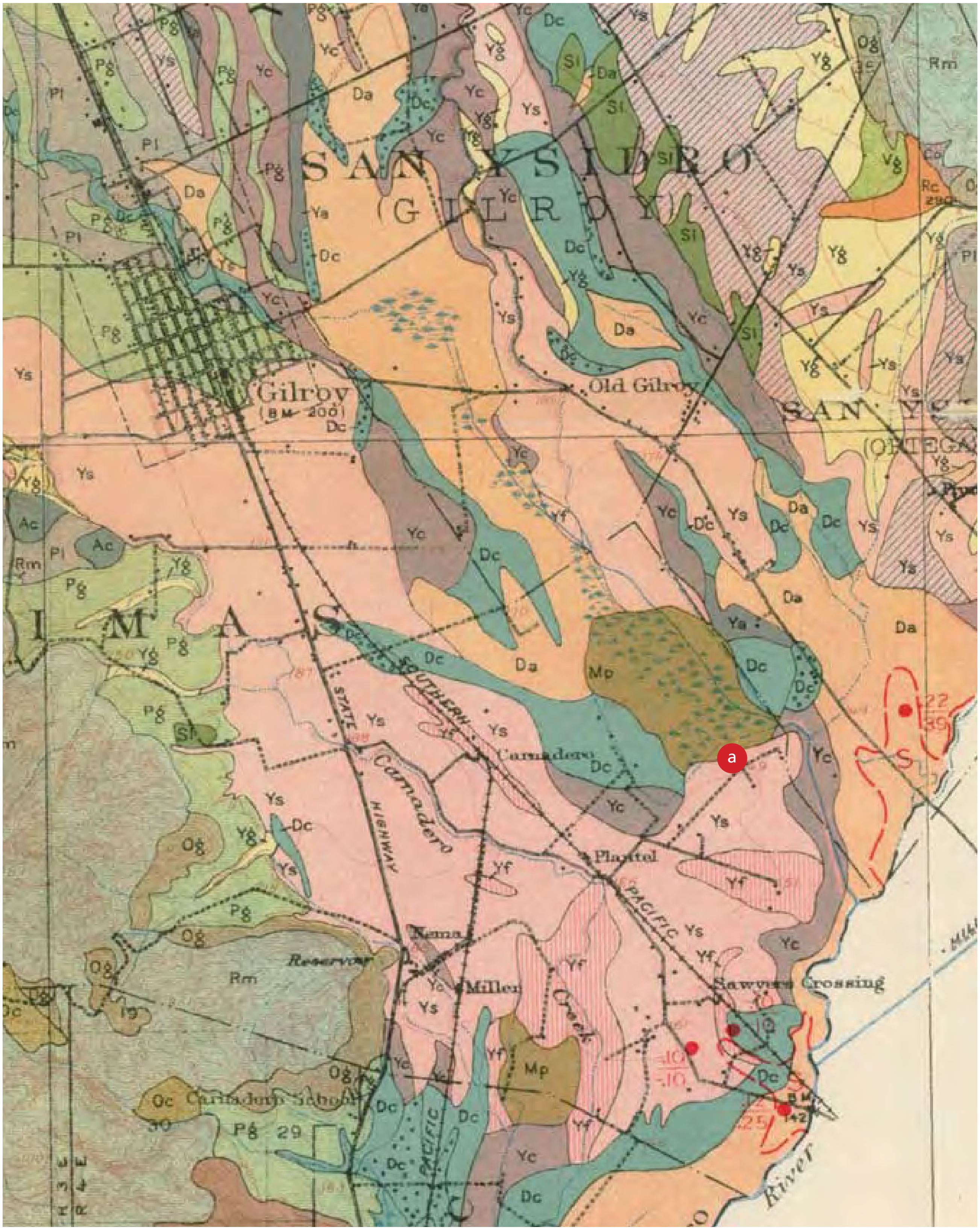


Figure 5.2. Patterns of alluvial topography, as shown by the 1923 soils map (Cosby and Watson 1927a). The natural levees of Carnadero and Llagas creeks can be seen in the shapes of the pink Yolo silt loam soils (Ys). The Carnadero levee branches out at Plantel, backing up the wetland shown at (a). Almost all of the roads, railroads, and townsites are located on the higher loams (Ys, Pg), rather than the flood-prone, bottomland clay soils (Da, Dc, Mp, Yc).

Wet meadows and alkali meadows

Wet/alkali meadows were mapped from eight historical soil types and four modern soil types. The selected soil types all had strong indicators of wetland conditions such as poor drainage, heavy clay soils, salt accumulation, vegetation, and/or agricultural limitations (table 5.1). These characteristics are distinct from most of the other relatively well-drained, coarser soils in the study area (SCCFC&WD 1972). As might be expected, a substantially greater area was documented in the historical surveys, conducted in 1923 (Cosby and Watson 1927a,b), than in the modern surveys, conducted during the 1960s (Isgrig 1969, Lindsey 1974).

Wet meadows are characterized by poor drainage conditions associated with dense clay soils and nearly flat topography, and are flooded for days or weeks depending upon rainfall events and their landscape position (fig. 5.3). These lands typically retain nearly all of the water that falls as rainfall and receive additional surface runoff or seepage from adjacent uplands (USDA 1951). As a result of high water retention and/or high groundwater level, these areas stay moist longer than adjacent, more well-drained lands.

Earlier historical descriptions affirm the hydrogeomorphic characteristics identified by soil surveys, with descriptions of meadows, overflowed lands, and late-season grazing.

Figure 5.3. Historical landscape photographs of wetlands are not common, but this "Scene on the San Martin Ranch" shows a seasonal pond in the wet meadows on the east side of Morgan Hill. (Unknown ca. 1896c, courtesy of History San José)

Table 5.1. Soil types indicative of wet and alkali meadow conditions.

Soil type (symbol)	Description	Source
Capay silt loam (Cs)	"restricted drainage" "injurious accumulations of alkali"	Cosby and Watson 1927b
Capay silty clay loam (Cy)	"restricted drainage" "flat and basinlike" "injurious accumulations of alkali are common"	Cosby and Watson 1927b
Dublin clay adobe (Da)	"black heavy clay with an adobe structure" "low basinlike areas where drainage is deficient"; "basinlike depressions"	Cosby and Watson 1927a
Dublin silty clay loam (Ds)	"restricted drainage"	Cosby and Watson 1927b
Conejo clay adobe (Ca)	"poor or restricted drainage"	Cosby and Watson 1927a
Dublin clay loam (Dc)	"flat, smooth surfaces, a high content of organic matter, and poor or restricted drainage"	Cosby and Watson 1927a
Yolo clay adobe (Ya)	"heavy clay or adobe structure"; "because of its heavy texture... planted to grain for hay"	Cosby and Watson 1927a
Yolo silt loam, compact subsoil phase (Ys)	"compact heavy clay loam or clay [subsoil]"; "relatively flat and shallow and not so suitable for orchards" [west side instances]	Cosby and Watson 1927a
Clear Lake clay (Cg/Ck) and Clear Lake clay, drained (Ch)	"poorly drained clays"	Lindsey 1974
Pacheco clay loam (Pd)	"poorly drained"	Lindsey 1974
Sunnyvale silty clay, drained (Sv)	"poorly drained silty clays"	Lindsey 1974
Willows clay (Wa)	"generally ponded during winter"; "no well-defined drainage channels"	Lindsey 1974

Figure 5.4. The former wet meadows east of Llagas Creek, flooded in February 1952 (A) and the same site in 2007 (B). Modifications to reduce overflow (inset) include drainage channel (note cattails in foreground), culvert under bridge crossing, and raised roadway. (A: Unknown 1952, courtesy of the Gilroy Museum)

Surveyor Sherman Day reported that he was in a wet meadow (Dublin clay adobe) in June 1854: "in meadow land, wet in winter." Overflow of the wet meadows east of Old Gilroy was described as "[T]he water, or I might term it a moving lake, has been known to be between two and three miles wide, and from thee [sic] to ten feet deep" (Gilroy Advocate 1869a; fig. 5.4). Bayard Taylor was impressed at finding that in the Soap Lake floodplain, the "meadows were still green" even though the soil of the surrounding valley "was more parched and arid than when I passed before" (Taylor 1850). The long-lived meadow grasses of the Soap Lake floodplain were much of the engine behind the Gilroy dairy industry, the Hollister hay industry, and supra-regional ranching operations such as Miller & Lux, providing rare late-summer pasture (Shortridge [1896]1986, Broek 1932, McCallum 1974).

The wet and alkali meadows were dotted with small depressions and swales, creating topographic and botanical variation. For example the wet meadows between San Felipe Lake and Llagas Creek included a broad "swale" described as 300 m (1000 ft) wide by Healy in 1858. The feature remains visible as an expansive darker area in early aerial photography, and was also depicted as "overfl[owed] lan[ds]" in the partially damaged map of the Las Animas Rancho (McDonald 1852(?)c). Broad and shallow swales such as these would have had deeper, more annually consistent overflow with longer duration than surrounding portions of the wet meadows. Local residents recollect observing numerous "potholes" in the western Bolsa, on both sides of Highway 25 (Morgan pers. comm.).

After extensive drainage by the 1970s, the wettest of these areas were described as being flooded about once every five years since "[d]rainage has been improved because of the general lowering of the water table in the valley," suggesting that these areas probably flooded on a substantially more frequent basis under natural conditions (Clear Lake, Pacheco, and Sunnyvale series; Lindsey 1974). Within these vast seasonal wetlands were smaller areas of perennial wetland. Except for occasional willow groves, taller vegetation was uncommon on the "treeless plain" (Broek 1932).

> *"During the winter most of this 'Bolsa' is wet, evaporation after the rains leaving a white alkali cover on the fields and roads."*
>
> — BROEK 1932

A substantial portion of the seasonally wet meadow lands was affected by the accumulation of soluble salts. While seasonal wetlands extended widely on both sides of the Santa Clara-San Benito County line, the alkali-affected portion was confined almost exclusively to the San Benito County side - the "Llano del Tequisquita." This area (the Hollister plain west from roughly the Hollister Airport to the county line, and crossing into Santa Clara County in several places) was known as "the land of alkali" - a broad, open plain with an unusual mosaic of saline and non-saline wetland habitat types, and also called the Bolsa ("pocket"; fig. 5.5).

Historical data describe ecological and hydrological characteristics that we would ascribe to alkali meadow (or alkaline grassland), including salt-tolerant vegetation associated with inland playas and saline marshes. Common species in the "salt grass pastureland" (Broek 1932) were saltgrass (*Distichlis* sp.) and pickleweed (*Salicornia virginica*). Numerous now rare plant species were also probably found. Jepson (1896) reported San Joaquin saltbush (*Atriplex joaquiniana*) in the area. Day (1854) noted a clover, likely saline clover (*Trifolium depauperatum var. hydrophilum*), which has been found in the vicinity as recently as 1995 (Hillyard 1995) – suggesting some persistence of alkali conditions despite agricultural drainage and flushing.

A white alkali crust was common on the surface after rains: "During the winter most of this 'Bolsa' is wet, evaporation after the rains leaving a white alkali cover on the fields and roads" (fig. 5.6; Broek 1932). These areas may have had shorebird habitat value similar to the playa-like salt

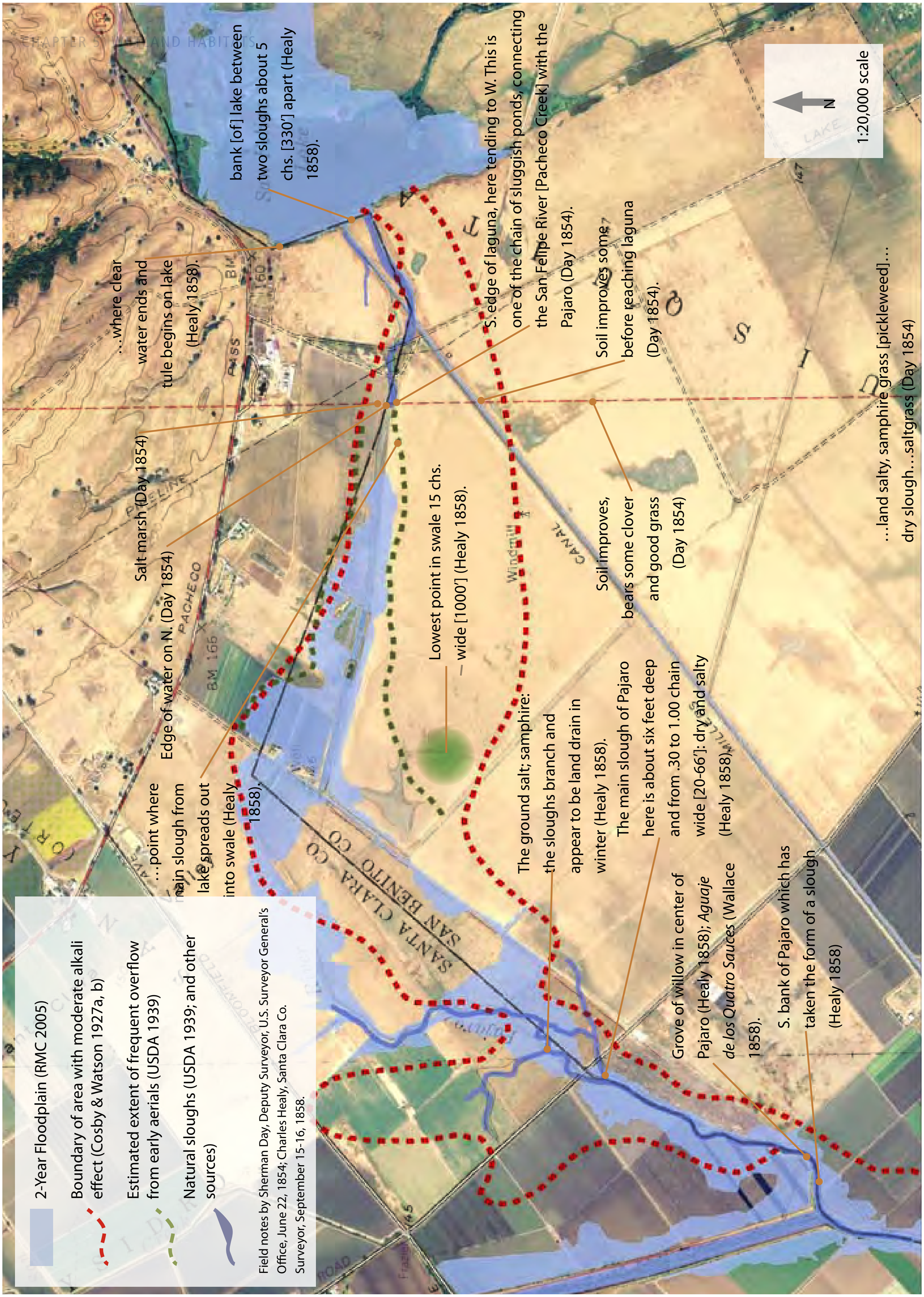


 Figure 5.5. Selected historical evidence describing the alkali meadows, sloughs, swales, and wetlands between San Felipe Lake and the Pajaro River.

pans found along the edge of South San Francisco Bay (Goals Project 1999); a number of shore bird species are still observed in the area today (PWA 2008). In the alkali meadows on the Santa Clara County side of the county line, Cosby and Watson (1927a) described "a great deal of common spikeweed (*Hemizonia pungens*)," which is presently common in alkaline seasonal wetlands in the Central Valley. Broek also emphasized saltgrass as the dominant vegetation in the larger alkali plains of the Bolsa. Evidence of alkali deposits is prominent in 1939 aerial photography (fig. 5.7). While such areas are less prominent today, alkaline soil conditions and salt marsh/alkaline meadow plant communities (e.g., saltgrass and alkali heath) can still be found in the area (PWA 2008).

There is also evidence that the alkali meadows of the Bolsa could be considered "flower fields," herbaceous communities dominated by showy wildflowers (Roof 1971). When subject to disturbance in recent years, fields along Highway 25 have displayed native wildflowers (e.g., *Plagiobothrys stipitatus*, *Downingia* spp., large stands of bull clover (*Trifolium fucatum*)), likely reflecting the historical floristic community still present in the soil seedbed (Morgan pers. comm.).

Freshwater ponds and marshes were scattered within the alkali meadow matrix. Henry Coletto observed numerous small depressions, particularly in the western Bolsa before more intensive agricultural modification post-1970. These seasonal ponds held water during winter and spring, attracting large numbers of waterfowl and shorebirds (Morgan pers. comm.). Early aerial photography may show evidence of this "pothole" landscape. Several dozen distinct features that could be ponds are visible in early imagery in the western Bolsa, ranging in diameter from about 6 m (20 ft) to 24 m (80 ft). One of the pre-colonial place names for the Bolsa area was "We-leh-lish-mo," or "place of the salamanders" (Ketchum pers. comm.), which is consistent with the picture of seasonal ponding, likely supporting the California tiger salamander and other amphibians.

Figure 5.6. Jan Otto Marius Broek took this photograph in 1931 to illustrate the salt effects in the Bolsa. The caption reads "View towards the northeast over the alkali flat of the 'Bolsa'; the dirt road covered with a white salt crust." (Broek 1932)

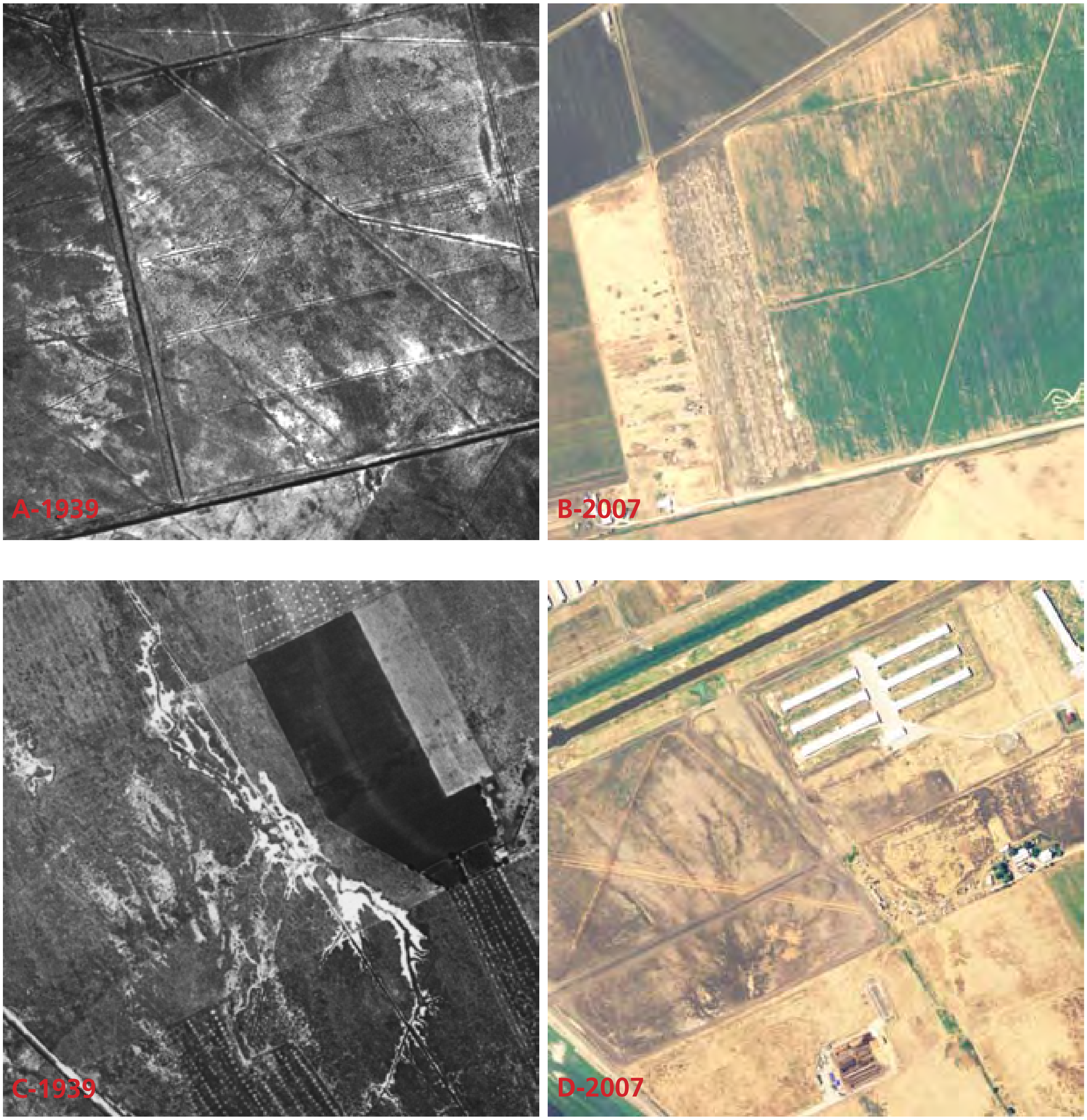


Figure 5.7. Mineral deposits evaporated from seasonal standing waters can be seen as white patches in early aerial photography of the Bolsa (A). A network of large and small ditches drain the area. Alkali deposits can be seen within a complex pattern of sloughs and swales in 1939 (C); small remnants may be visible in contemporary imagery (D). (A and C: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; B and D: USDA 2005, courtesy of NAIP)

Some permanently wet features are recorded in earlier documents. For example, about a mile west of the Frazier Lake Road-Shore Road intersection, Day (1854) struck a "tulare pond" about 10 m (30 ft) in diameter within a "wet marsh with tulares" over 150 m (500 ft) wide. This chance encounter suggests that there were likely other similar features distributed within the alkali meadow, and several freshwater marshes were in fact shown by McCray (1907). Additionally, freshwater ponds and marshes were found along the Calaveras fault trace in the Tequisquita Slough area. Seasonally wet swales and sloughs and a few perennial freshwater sloughs (e.g., Tequisquita) coursed through the alkali meadows.

Valley freshwater marsh

Perennial valley freshwater marshlands were important features in the native landscape, providing water sources during the long dry season. They are also relatively distinct features in the field, evidenced by characteristic, and generally tall wetland plant communities and associated hydrological conditions. The habitat type appears to have been consistently recognized within different cultural and professional contexts because of basic practical characteristics. These were places that were difficult to walk through but that might have water for cattle or horses. Given their relatively restricted distribution, they also served as landmarks or boundaries.

> *". . . the peculiar property of tule land, i.e., shaking or trembling as one walks or drives over it."*
>
> – HARRISON CA. 1888

In Mexican-era maps, the terms ciénega (swamp or marsh; e.g., U.S. District Court, Northern District 1873a) and tular (place of tules) serve as indicators of valley freshwater marsh. These features often coincided with equivalent depictions by early American surveyors. Conventional map symbology for perennial freshwater marsh has been remarkably consistent for centuries, represented, in various permutations by parallel, often broken, horizontal lines with vertical "tufts." Such conventions were observed by McDonald (1852(?)a,b,c), Healy (1858b), Thompson and West (1876), USGS (1917), and others.

Textual descriptions provide additional evidence. Indicative terms include swamp, marsh, and tule, referring to the distinctive tall rush in the genus *Schoenoplectus* (formerly *Scirpus* sp.). For example, surveyor Dyer (1861), writing in September, recorded "low marshy land covered with tule and flags" in the area of the present day Llagas Creek flood control channel and South County Regional Wastewater Plant. A map of the Las Animas Rancho confirms the presence of tule swamps here (fig. 5.8), while Cosby and Watson (1927a) note that "sedges and water-loving plants are the main vegetation" and the water table, despite a drainage ditch, remained within 1 m (3 ft) of the surface in the dry season (and floods to a depth of 2 m/6 ft in places). Local residents referred to this place as "the swamp" (Sturla pers. comm.).

Healy (1858a) confirms the boundary between open water and freshwater marsh on the margin of San Felipe Lake: "... where clear water ends and tule begins on lake." Harrison (ca. 1888) notes the extent of valley freshwater marsh surrounding San Felipe Lake: "near the lake much of the country possesses the peculiar property of tule land, i.e., shaking or trembling as one walks or drives over it. In this section vegetation grows very rank..." Tules around San Felipe Lake were tall, requiring one observer looking for a drowning companion to climb a fence in order to "[overlook] some tules intervening" (Gilroy Advocate 1869b).

Valley freshwater marshes commonly included open waters too small to map. For example, surveyor Day described "a tulare pond ½ chain diameter [10 m/33 ft]" in a "marsh" encountered while crossing the Soap Lake alkali meadows (Day 1854). Similarly, the diseño of Rancho de Las Animas shows several ponds within the large willow grove/tule marsh at the bottom of Llagas Creek (McDonald 1852(?)c; fig. 5.8).

Figure 5.8. Freshwater wetlands and willow swamps at the confluences of Llagas Creek and Uvas-Carnadero Creek with the Pajaro River. Llagas Creek enters a "Willow and Tule Swamp" with significant freshwater ponds at top; Uvas-Carnadero Creek spreads into a "Willow Swamp below". The Pajaro River flows from top to bottom at right. (MacDonald 1852(?)c, courtesy of The Bancroft Library, UC Berkeley)

Valley freshwater marsh was often associated with willow groves. This was particularly notable at the Llagas Creek wetlands, which were referred to as "willow and tule swamp" by American maps and alternately as ciénega/tule marsh or sausal/willow grove by other sources. While the Carnadero willow grove does not seem to have had as much freshwater marsh (it was consistently referred to as willow grove/sausal), it did apparently have a significant adjacent freshwater marsh or ciénega at the mouth of Tar Creek (U.S. District Court, Southern District [184-?]c; USGS 1917).

Perennial freshwater ponds and lakes

One major freshwater lake was identified in the study area, the still extant San Felipe Lake. In addition, several perennial ponds were noted along Gavilan and Llagas creeks which were probably large, persistent stream pools.

San Felipe Lake, a sag pond along the Calaveras fault, is a rare and ecologically significant wetland resource in the region. Here, water depth was sufficient to maintain a perennial open water lake. Under natural conditions, the boundary between perennial open water and emergent wetland vegetation can vary substantially over time in lakes. Wetland plants can invade shallow ponds when inundation depths decline due to sedimentation or reduced rainfall years. Conversely, wetter conditions can drown out vegetation, resulting in expanded open water area. There is no evidence that the open water portion of San Felipe Lake dried up in historical times, as it is illustrated by a number of sources over the past two centuries. It is possible that little or no open water persisted in times of extreme drought, as was observed in 1977 (Smith 2007), but higher historical groundwater levels probably made drying out unlikely.

San Felipe Lake is deep enough to have persisted through variations in climate and drainage, with depth presumably controlled by the Calaveras fault and sedimentation rates. Historical evidence suggests the lake had sufficient depth and size to be termed a "lake" according to contemporary definitions (> 10 ha/25 ac and 2 m/6 ft deep; Cowardin 1979).

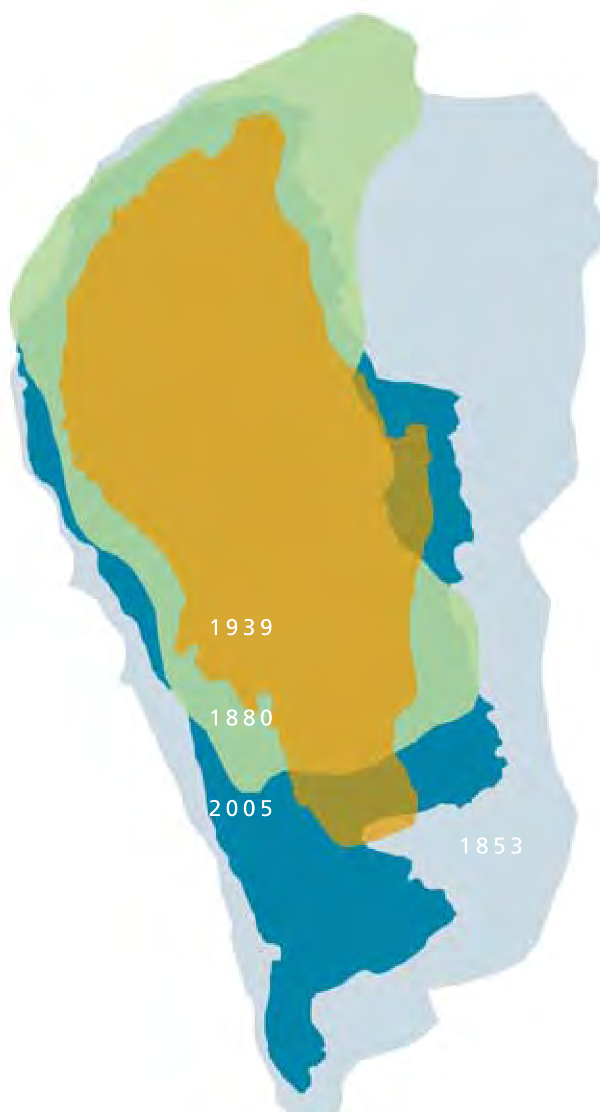
In a tragic account from 1869, the *Gilroy Advocate* describes a duck hunter drowning in the margins of the lake: "in 8 feet of water, about 60 feet from shore" (Gilroy Advocate 1869b). While the location of the incident is not stated, the water depth this close to shore in a lake hundreds of meters across across suggests that depth was commonly equal or substantially greater than 8 ft (2.5 m). This contrasts with present day summer water depths of 1 m (3 ft; Smith 2007).

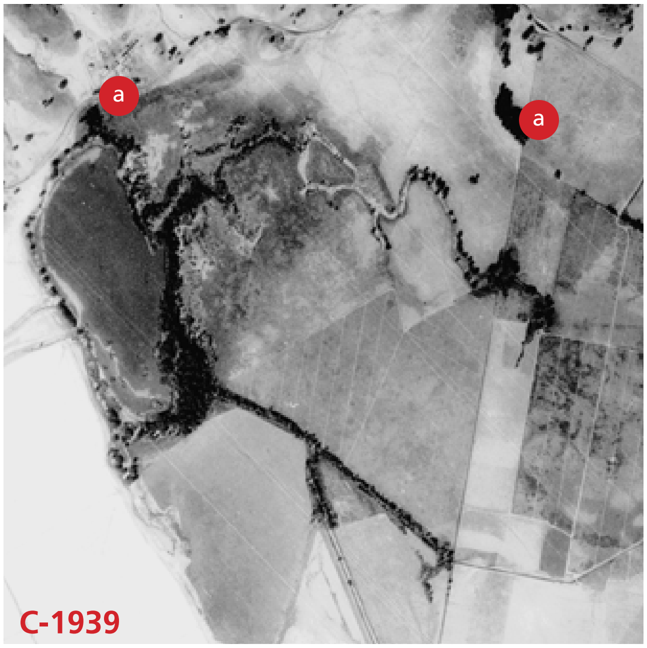
> *"The land is very good, with abundant pasturage, and it has innumerable large lagoons of fresh water and three our four villages of heathen, who, by means of rafts, catch a great deal of fish in the lagoons."*
>
> — CRESPÍ DESCRIBING SAN FELIPE LAKE AND SURROUNDING WETLANDS IN THE SPRING (MARCH 23) OF 1772

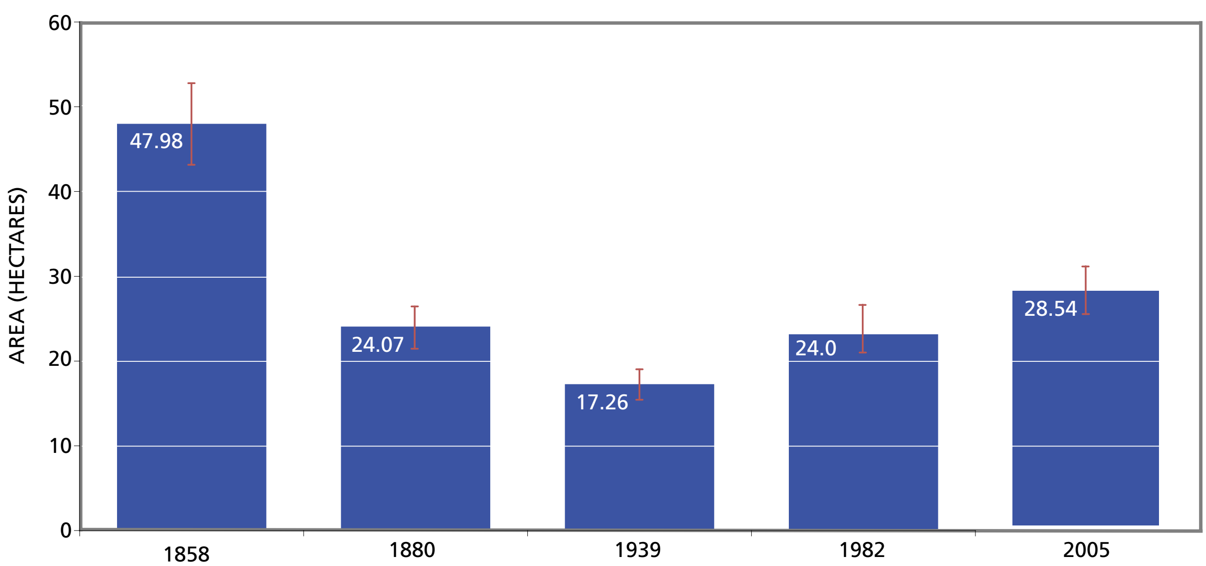
While the lake has persisted through climatic and land use changes, the extent of open water appears to have been substantially larger in the 1850s and 1860s, prior to major hydromodification. A newspaper article from 1860 describes the lake as "about three square miles in dry season." While this account is no doubt substantially exaggerated, it does imply that the lake used to be significantly larger than it is at present (Daily Alta California 1860, in Roddy 1995). More precise information comes from Healy's 1858 map establishing the county boundary, which is confirmed by his detailed survey notes (Healy 1858a,b; Healy 1868). He depicts the open water portion of "Lake San Felipe" as extending substantially farther west than do most later documents, and emphasizes this with the label "deep water." This depiction is reaffirmed by his field notes. The location of this observation corresponds with the open water/freshwater marsh margin depicted in his map (fig. 5.9). The survey was accomplished in September, so the greater lake extent is unlikely to have been a seasonal phenomenon (1856-58 were also relatively average water years).

Healy's map and survey represent the earliest reliable picture of the area and suggest the lake was at least 48

Figure 5.9. The history of San Felipe Lake is shown in a series of maps and aerial photographs. The lake is shown as substantially larger in 1858 (A) than in the subsequent views, with prominent sloughs in both 1858 and 1880 (B). Digitizing the open water areas from the georeferenced sources allows a comparison of area (right) and in the bar chart (facing page). The lake appears to have receded substantially in 1939 (C), following drought; lake bottom sediments were exposed and willow trees invaded the lake margin at that time. Apparent expansion of willows into the former "Tules and Salt grass" between 1858 and 1880 can be seen in the lower right of those images. Several historic willow groves that have maintained their position through time are identified at (a). (A (Healy 1858b) and B (Healy 1880a), courtesy of the San Benito County Recorder's Office; C: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; D: USDA 2005, courtesy of NAIP)







San Felipe Lake area over time, with estimated measurement error ha (120 ac) in size, compared to < 30 ha (70 ac) today (fig. 5.9). The 1858 measurement is conservative - the open water area could be reasonably interpreted to have extended farther to the east, which would add about 8 ha (20 ac). These data indicate that the lake has decreased in size by 40-50%. This change in the middle decades of the 19th century is corroborated by an observer in 1888, who noted that "by the slow but sure processes of nature and the ingenuity and industry of man, the boundaries of this water have been reduced until now they circumscribe a lake (Soap Lake) covering not more than 100 acres" (Harrison ca. 1888; the phrase "Soap Lake" sometimes referred to San Felipe Lake). This suggests that hydromodifications of the 1870s and 1880s – for example, Millers Canal – had an immediate impact on the extent of San Felipe Lake.

The next detailed map of the area, produced in 1880, shows an open water portion similar to that seen in 1939 aerial photography and subsequent maps. It is possible that the construction of Millers Canal in 1873-4, and associated adjustments to the outlet mouth, had already lowered lake levels by this time. Aerial imagery following the droughts of the 1930s shows a heavily receded lake extent, with the expansion of willow trees into former marshland areas (fig. 5.9).

The construction of Millers Canal and Emery Canal, among other channel modifications, had a considerable impact on the entire Bolsa. "Due to the construction of drainage canals and to improvements on the natural water courses," writes Broek (1932), "a number of lagoons and swamps formerly covering this eastern part of the flat have disappeared."

We also mapped one large playa (a seasonal or intermittent lake). We refer to the feature as playa because it was, at least in part, associated with alkali soil conditions. The feature was part of the wetland complex at the downstream end of Llagas Creek and was exceptionally well documented. A number of mid-19th-century surveys described the feature as "Lake" (fig. 5.10) and some indicate boundaries quite precisely. One survey, by county surveyor Day (1854), calls the feature the "Pajaro Lake," presumably referring to its location at the head of the Pajaro River, transitional between Llagas Creek and the Pajaro. Because of the lake's position on the boundary of two adjacent land grants, it was described and/or mapped a number of times in different seasons, providing a substantial data set indicating seasonal variation (fig. 5.10). The lake was clearly inundated regularly, and to a sufficient depth that surveyors were compelled to go around its margin well into late spring. Size decreased into summer months and the indication from Dyer (1861) is that the feature was, in an average water year, dry by the late summer.

Willow groves

Willow groves were documented by a number of historical sources with indicative terms such as sausal, willow swamp, or willow lands. Map symbols commonly indicated trees within wetland areas (e.g., figs. 5.8 and 7.29). Sources of independent origin often confirmed the same feature. Where county surveyor Healy described a willow grove in 1858, soil scientists Cosby and Watson observed a "poorly drained" area "support[ing] a growth of water grasses and willows" (Cosby and Watson 1927a), both confirming the feature and indicating substantial persistence for multiple decades.

Willow groves, or sausals, are commonly associated with springs. Groundwater often emerges at the distal end of alluvial fans, where silt or loams meet the clay-rich, fine-grained soils of the lowlands. Historically, artesian waters often emerged at this point (e.g., associated with springs and the clay/loam transition near Stevens Creek, and at similar positions on Guadalupe River and Willow Glen; SFEI unpublished data) . Similar patterns were found around Soap Lake.

Around San Felipe Lake, willow grove locations closely correspond to the margin of alkali soils, primarily where the salinity was weakest. In fact, Healy – in the absence of any other defining feature in the flat Soap Lake landscape – used the margin between saltgrass and willows to demarcate the county boundary. Similarly, willow groves were often found at the very edge of tidal marsh in south San Francisco Bay, indicating some limited salt tolerance (Collins and Grossinger 2004).

Historical documents provided some evidence for the interior features of willow grove habitat. Herrmann (ca. 1870) showed multiple sloughs running through the Carnadero grove. Both McDonald (1852(?)a,b,c) and Dyer (1861) showed, in the same position, patches of freshwater marsh within the Llagas willow grove. McDonald also indicated freshwater ponds. It is likely that these components existed within the other large willow groves but were not shown.

Native Fish Assemblages

The following section uses historical evidence for wetland habitat conditions and historical records of fish in the watershed (Appendix 2) to reconstruct probable native fish assemblages associated with major habitat types (Appendix 3).

Perennial freshwater ponds, lakes, and lagoons

Perennial ponds, lakes, and lagoons shared many of the same fishes found in similar lowland habitats of the Central Valley (Gobalet and Fenenga 1993, Moyle 2002) and lower Pajaro River floodplain (Gobalet 1990). San Felipe Lake formed the most extensive perennial lake in the upper Pajaro River watershed and, as such, consisted of a complex mosaic of open water bordered by permanently flooded valley freshwater marsh, wet meadow, alkali meadow, willow grove, floodplain sloughs, and swales (see fig. 7.5). The aerial extent of flooding and persistence of ponded water would vary from year to year depending on regional and local precipitation and runoff patterns, which would in turn affect fish assemblage membership and distribution. Fishes collected from San Felipe Lake in 1916 include the extinct thicktail chub (SU 23795), hitch (SU 37850), and Sacramento blackfish (SU 37876; see Appendix 2 for specimen numbers). Other lowland fishes collected by Snyder (1912) and identified from archeological sites adjacent to Elkhorn Slough, also probably found in San Felipe Lake (Gobalet 1990), include Sacramento pikeminnow, Sacramento sucker, prickly sculpin, threespine stickleback, Sacramento perch and tule perch. Steelhead adults and smolts likely used these floodplain habitats as migratory pathways when flooded.

Intermittent ponds, lakes, and lagoons

Pajaro Lake was a large seasonal lake/lagoon on lower Llagas Creek (fig. 5.10). The lake fluctuated widely in size and apparently dried completely in some years (Wallace 1858a,b; Dyer 1861). During years when Pajaro Lake was persistently flooded, fish assemblages were likely similar to those found in perennial lakes, ponds, lagoons, and valley freshwater marsh habitats. During drier years fishes would likely either migrate into tributary streams or floodplain sloughs as the lake dried and/or be trapped and perish. Fishes likely occurring in intermittent ponds, lakes, and lagoons such as Pajaro Lake include Sacramento blackfish, hitch, thicktail chub, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin, Sacramento perch, and tule perch. Steelhead adults and smolts likely used these floodplain habitats as migratory pathways when flooded. Many native fishes are well adapted to seasonal flooding patterns, with the ability to move downstream as water levels recede (Moyle et al. 2007). However, under some conditions it is probable that as floodwaters receded some steelhead would be trapped in temporary wetlands.

Perennial valley freshwater marsh

Perennial valley freshwater marsh was often closely associated with perennial lakes, ponds, lagoons, and floodplain sloughs, typically following a hydrologic gradient of increasing water depth and duration towards

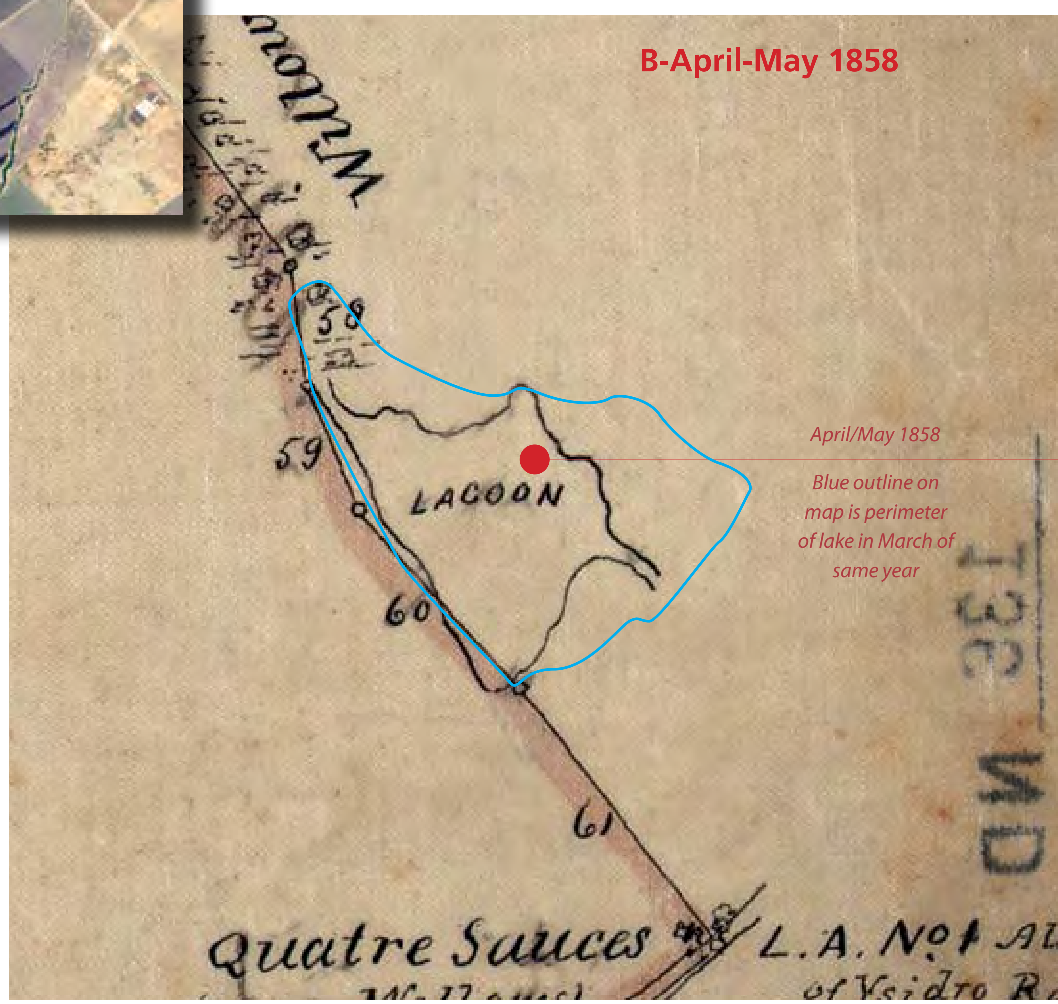
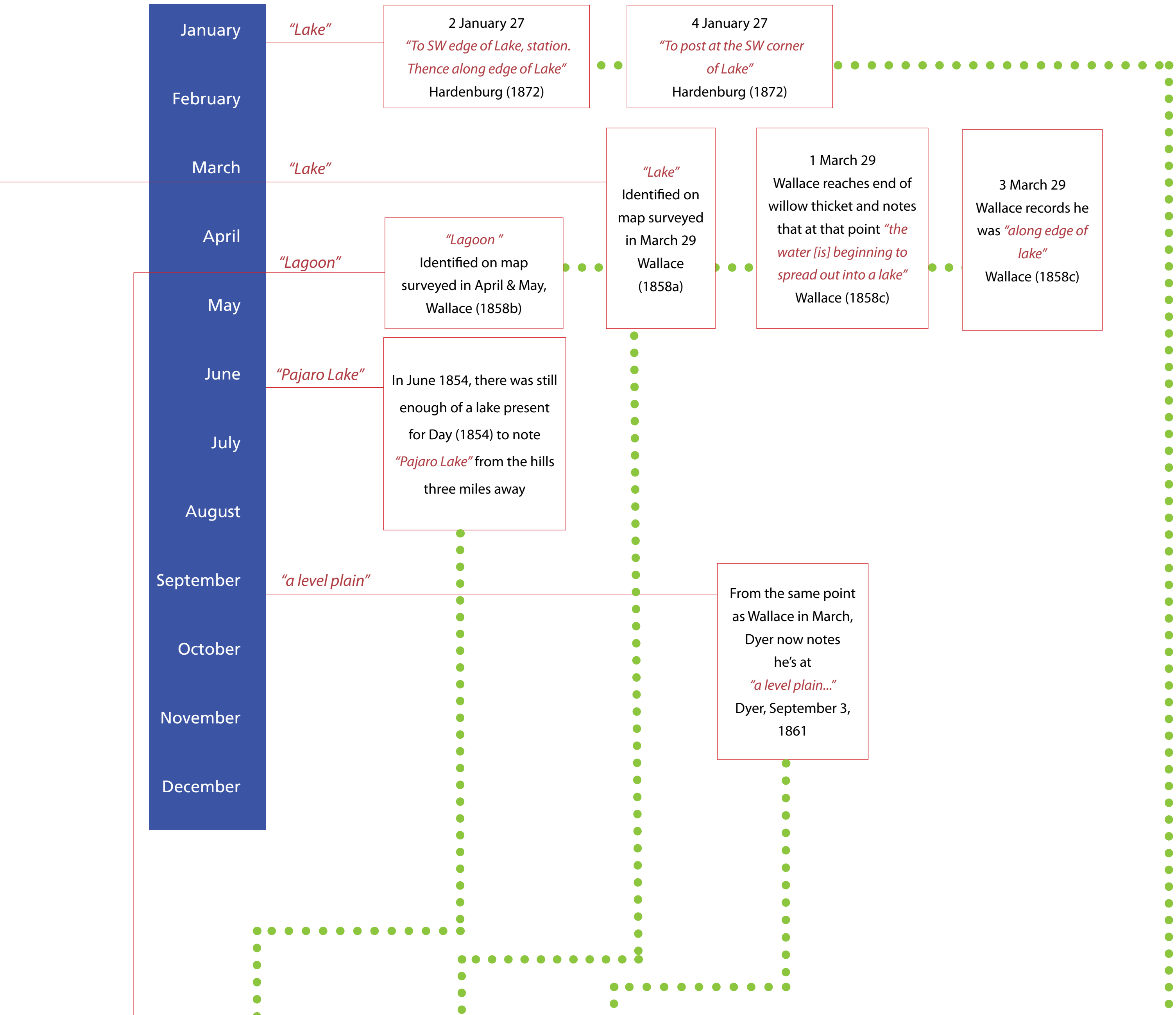
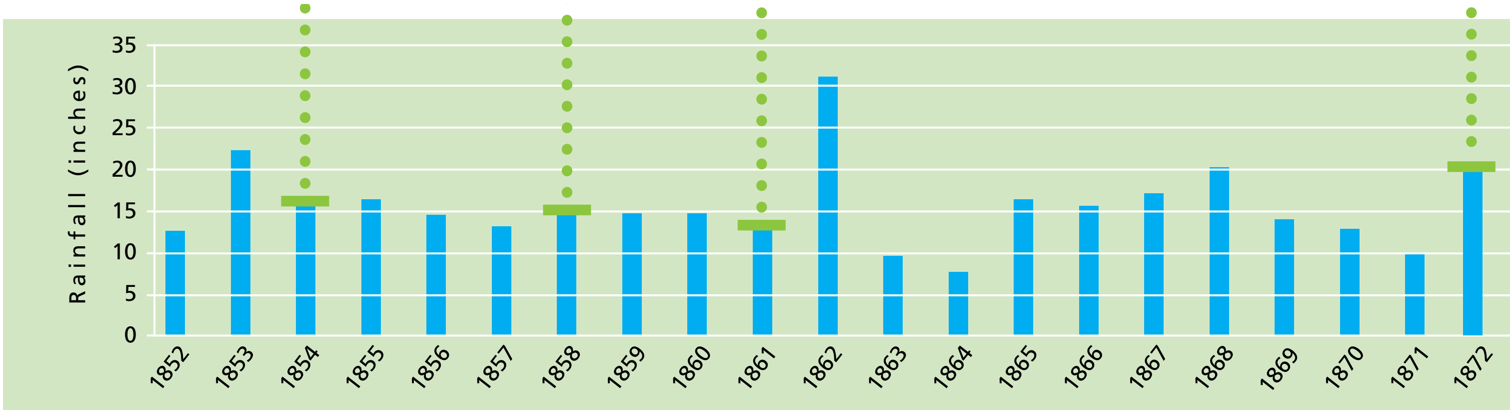


Figure 5.10. Seasonal variation of the "Pajaro Lake." The large seasonal lake or lagoon on lower Llagas Creek at Bloomfield Road was a unique feature in the region. Called "Pajaro Lake" by Sherman Day, it formed the boundary between the Las Animas and the San Ysidro ranchos, which is still evident in contemporary property lines. Maps made by Wallace in March (A) and April-May (B) of 1858, in which he showed the decreasing size of the lake, are shown at right. Some of the survey points are labeled with his field notes. Willow grove and marsh are shown along the survey line as it extends towards the upper left. The outlet forming the Pajaro River can also be seen. In the diagram on the facing page, repeated surveys describe the site in different seasons and years. The lake was sufficiently large and persistent to be seen from several miles away in June of an average water year and serve as a grant boundary (see Chapter 7). Yet by September (in another average water year), the area was dry enough to be referred to as "a level plain." (A (Wallace 1858a) and B (Wallace 1858b), courtesy of The Bancroft Library, UC Berkeley)



These observations were all made during relatively average water years.



the lake or slough. Large expanses of freshwater marsh were found bordering Tequisquita Slough and at the confluences of Miller Slough and Llagas Creek and Uvas-Cardanero creeks with the Pajaro River (see fig. 5.8). Presumably because of their immediate proximity to perennial ponds, lakes, and lagoons, valley freshwater marsh supported lowland native fishes such as Sacramento blackfish, hitch, thicktail chub, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin, Sacramento perch, and tule perch. Steelhead adults and smolts likely used floodplain sloughs as migratory pathways. The significance of these permanent wetlands, as well as the other wetland habitats, for steelhead rearing within the Pajaro River watershed is unknown. However, steelhead are known to rear on the floodplain of the Cosumnes River, a low elevation, perennial stream in the Central Valley (Moyle pers. comm.).

DISCUSSION

Wetland area has decreased precipitously since historical times for each of the major wetland types of south Santa Clara Valley. These changes have led to population declines for numerous wetland-associated species, requiring the designation of several species as threatened or endangered. At the same time, there is some evidence that in many places the topographic and hydrogeomorphic conditions are sufficiently intact to support significant habitat restoration (PWA 2008). We identified a number of remnant historical wetlands as well as recently recovered wetlands. These could

Figure 5.11. This willow grove appears similar in size and location in historical documents since 1858 (see fig. 5.9). Here the leaves of these deciduous trees (arroyo

provide models for future restoration and serve as nuclei for the recovery of larger functional systems. Despite the history of modifications, current conditions appear to have the potential to support successful wetland restoration projects in a number of places.

Residual features

Several fragments of the historical wetland landscape can be identified in the present-day landscape, particularly within the Soap Lake floodplain. While these are relatively isolated and fragmentary compared to the larger wetland mosaics of which they were historically part, they represent valuable landscape elements that should be recognized in conservation planning. For example, significant remnant willow stands occupy their precise historical position and appear to be thriving on the northern margin of San Felipe Lake (fig. 5.11). San Felipe Lake also represents a partial remnant of a major and unique geographic feature in the region – a large natural lake. Patches of alkali meadow vegetation persist in places throughout the Bolsa, indicating the persistence of alkali soil conditions (PWA 2008), and native wildflowers have returned in recent years under particular disturbance regimes (disking or plowing; Morgan pers. comm.).

Some of the small freshwater wetlands remaining in the vicinity around San Felipe Lake appear to be remnants of much larger historical wetlands.

willow, *Salix lasiolepis*) are changing color in December. Note the well-defined "browse line" in the willows' lower canopy, as nibbled back by cattle and deer.

"Accidental" recovery

In addition to these residual habitat features, we encountered several sites where portions of former wetlands have returned in the past several decades. Since water imports began in 1987, groundwater levels have recovered, enabling the recovery of wetlands in some places (figs. 5.12 and 5.13). Extra efforts to drain water or remove vegetation have been required to prevent reversion to wetlands in other places.

Willows have recolonized a portion of their historical extent at the South County Regional Wastewater Plant along Llagas Creek in Gilroy. Because of high artesian water, the southernmost percolation pond has been allowed to revert to natural vegetation since about 1984, such that a willow grove now occupies about 6 ha (15 ac), roughly half of the pond. Without regular vegetation management, willows would expand into neighboring ponds. In addition, an adjacent landowner has voluntarily fallowed 8-12 ha (20-30 ac) of his land, allowing wetland vegetation to reestablish next to the south pond, largely because high groundwater precludes successful farming on that patch (Rodriguez pers. comm.).

Mature willow trees can also seen along Bolsa Road, within the historical Llagas Creek willow grove, and Lovers Lane, within the extent of the historical Pacheco Creek willow grove. Along Lovers Lane, many of the street trees and yard trees are also willows (fig. 5.14).

Artesian flow has been maintained or returned to many parts of the Bolsa, and the fine-grained clay soils and depressional topography still remain fundamentally intact. While extensive drainage efforts have reduced the extent and frequency of seasonal flooding compared to historical conditions, the Soap Lake floodplain still remains subject to flooding on a two to five year basis (RMC 2005). Recent analysis of the potential for restoring floodplain wetlands suggests that many of the historical wetland habitats and functions could be successfully recovered through a coordinated conservation and restoration effort (PWA 2008).

Wetland mosaics

As wetland restoration efforts are considered, the historical landscape provides a template for the design of wetland landscapes. One of the prominent historical landscape characteristics was the repeating pattern of wetland habitat mosaics that occurred, in varying arrangements, at the major wetland areas of South Valley. This common pattern for south Santa Clara Valley wetlands includes open water ponds or lakes surrounded by perennial freshwater tule marsh, bordered by willow stands, and surrounded by wet meadow and/or alkali meadow (fig. 5.15). Large seasonal lakes or playas were also sometimes present. Where the topographic and hydrologic gradient was less steep, these habitat mosaics covered hundreds of acres; in other places they were compressed into a relatively small area.

This general pattern was highly consistent. As can be seen in the map of historical conditions (inside front cover), willow groves and freshwater marsh almost always co-occurred. Both habitats were always fully or partially bordered by seasonal wetlands, either wet meadows or alkali meadows. Perennial ponds were generally surrounded by freshwater marsh.

> Well-designed mosaics of freshwater marsh, willow grove, perennial ponds, and seasonal wetlands could provide a wide array of native species support functions within relatively small areas.

In contrast, today's permanent water bodies (such as reservoirs, water treatment ponds, and other water storage features) typically have little or no surrounding wetlands. The historical pattern (few freshwater ponds surrounded by large wetlands) has been inverted, such that modern ponds or lakes typically have only occasional fringes of wetlands at their margin. Similarly, willow thicket habitat is now almost completely limited to the margins of streams and flood control channels, while the historical groves were bordered by grasslands, wet meadows, and freshwater marshes.

The historical mosaics provided an array of habitat characteristics needed to support the different resting, foraging, and breeding support functions required by native species. For example, the small perennial ponds surrounded by open meadows likely provided ideal habitat for the California red-legged frog. (In fact, South Valley's wetlands may have accounted for some of the 40,000+ frogs harvested annually from Santa Clara County in the mid-1890s; Jennings and Hayes 1985.) California tiger salamander, tricolored blackbird, southern Pacific pond turtle, least Bell's vireo, and other wetland-associated special status species were likely well supported in these local wetland mosaics. The floodplain wetland mosaics located at the bottom of Uvas-Carnadero, Llagas, and Pacheco creeks also probably provided important food resources for native fishes, including outmigrating steelhead smolts. Loss of these habitats may be a contributing factor in the overall decline of local steelhead populations. While there is some concern about the potential for stranding within restored floodplain wetlands, recent research on the Cosumnes River floodplain has found minimal stranding of native fishes (Moyle et al. 2007). Floodplain restoration should be designed to minimize stranding while increasing habitat for rearing and feeding by native fishes.

Given that modern, restored habitats will inevitably be smaller than their historical counterparts, having an appropriate array of related, contiguous habitats can maximize the benefits of wetland restoration for target species. For example, while San Felipe Lake retains a significant portion of its historical extent (50-60%), the freshwater marshlands bordering the lake have been almost completely eliminated (93%). Willow groves and seasonal wetlands have declined dramatically as well. Recovery of some of the wetland habitat mosaic around the lake might greatly increase the ecological functions of the site.

There are a number of opportunities to reestablish wetland mosaics in each of the three major historical wetland areas. There is potential along lower Llagas Creek, along the Pajaro River-San Felipe Lake-Pacheco Creek alignment, and along lower Carnadero Creek, where the SCVWD Carnadero Preserve is located. Restoring functional wetland mosaics in these areas, coordinated with invasive species/predator management (e.g., Western cowbirds, bullfrogs), could make a significant contribution to the recovery of a wide range of native species.

Potential sites for restoration and conservation

The heterogeneous distribution of wetlands within the historical landscape can help target priority sites for restoration and conservation. These areas are most likely to possess the physical characteristics conducive to wetland formation and maintenance, such as clay soils, depressional topography, and near-surface groundwater. Identifying these sites can help improve the chances of restoration success. There are a number of such sites on the south Santa Clara Valley floor.

In addition to the wetland restoration opportunities at the downstream end of major creeks, there is also potential to recover some of the alkali plain habitats that characterized much of the Bolsa and Soap Lake floodplain (especially the western Bolsa). The unusually flat topography, relatively high groundwater, persistent alkaline soil conditions, and observations of salt-tolerant vegetation and occasional native wildflower displays suggest a generally conducive physical context for restoration. Reestablishment of alkali meadow mosaics – which included alkaline grasslands and wetlands, with scattered seasonal and perennial ponds – would involve several components. The natural topographic and hydrological variation that created these patterns

Figure 5.12. Wetlands such as this small marsh in an older orchard on Lovers Lane (planted when groundwater levels were lower) are an indicator of changes in near surface groundwater levels in the past two decades.

Figure 5.13. Reestablished willow grove at the South County Regional Wastewater Plant.

Figure 5.14. In the former Pacheco Creek willow grove, willows remain part of the landscape, alongside roads and houses.

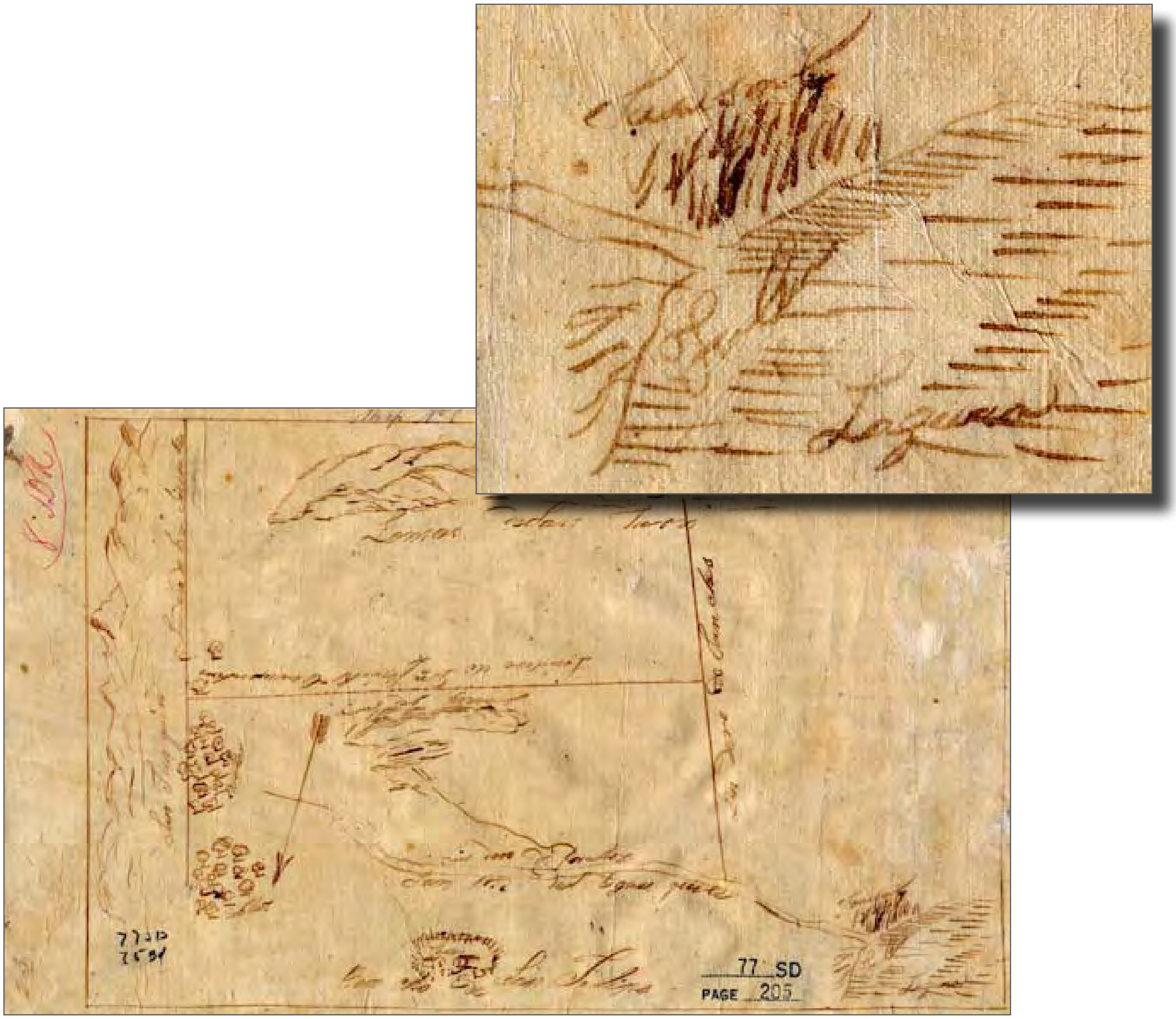


Figure 5.15. The classic wetland mosaic of open water-tule marsh-willow grove found in the larger south Santa Clara County Valley wetlands is illustrated in this diseño of the Rancho Bolsa de San Felipe produced circa 1840. The inset shows "Sausal," "Tular," and "Laguna" at the mouth of Tequisquita Slough into San Felipe Lake. (U.S. District Court, Southern District [184-]f, courtesy of The Bancroft Library, UC Berkeley)

may exist in places, and might be able to be re-created in other places through excavation and decommissioning of drainage ditches, based upon historical patterns. Carefully structured disturbance regimes such as the disking of fallow and grazed lands may allow expression of the dormant native seed bank.

Although not directly studied here, wetlands were also not uncommon in the hills of south Santa Clara County (Grossinger et al. 2007b). Cosby and Watson (1927a) noted vernal pool-like conditions in certain clay-rich upland soils: "numerous basinlike depressions occur in which the storm waters tend to become impounded, resulting in small temporary lakes or ponds." Several perennial wetland features were documented by other sources, including Twin Lakes, a historical chain of ponds and wetlands that are still present in a small valley (USGS

1917). Many of these moist, upland valleys were chosen for reservoir sites, but the lagunas recorded by Day (1854) just north and west of San Felipe Lake appear also to still be intact, based upon contemporary aerial photography (Grossinger et al. 2007b). These extant upland wetlands may be important features to consider for conservation.

Disturbance regimes and stewardship

The habitat patterns within historical wetland mosaics were controlled by broad scale, slowly changing hydrogeomorphic controls, such as microtopography, soil type, and artesian conditions. But the finer scale attributes of these habitats were shaped by disturbance regimes that created variations in stand structure, canopy structure, plant distribution, and other characteristics that are important to native species. In the absence of such disturbance, habitat support functions may become limited. For example, willow groves that provide a mix of dense, mature thickets (favoring interior species), and younger, open areas (favoring taxa such as least Bell's vireo) likely support greater overall ecosystem function than single age, homogenous stands (Rottenborn pers. comm.). Similarly, wildflower populations in former alkali meadows appear to benefit from occasional plowing or disking (Morgan pers. comm.).

Ideally, wetland mosaics would be restored within a floodplain context, where they would be subject to regular disturbance by floods to maintain a diverse array of habitat characteristics. Within watersheds regulated by large dams, pulse flows timed to maximize ecological benefits could be part of maintaining an appropriate disturbance regime.

When not part of an active floodplain, willow groves could also be artificially disturbed through a stewardship plan designed to mimic natural processes. These kinds of activities might be modeled on native management practices, which likely affected the canopy structure of willow groves and associated species support functions for thousands of years prior to Euro-American settlement. An often overlooked aspect of willow riparian restoration is the management practices of pre-colonial peoples that likely contributed to the habitat characteristics of these features.

It has been well documented that local tribes made great use of various willow taxa for basket material, construction material, medicines, and other utilitarian uses–often harvesting a tremendous volume of plant material annually (Bocek 1984, Anderson 1999). This historical habitat modification, while poorly studied, likely had substantial effects on the form and function of existing habitats and the associated support functions, particularly for native bird species. Plants were managed for specific characteristics, including flexibility, straightness, minimal lateral branching, bark color/lack of blemishes, diameter, and length (Anderson 1999).

Given their cultural importance, it is likely that significant portions of willow groves were managed by Mutsun-speaking people for specific products in the South Valley area, probably focusing on different areas for different products (i.e. smaller basket shoots vs. larger, more robust shoots for construction material). Long-term modification of these plants' architecture would have influenced the structure of nesting and foraging habitat for species such as least Bell's vireo and other riparian-associated species. Regularly harvested plants would have generated a greater number of epicormic shoots when compared to unmanaged plants, resulting in greater leaf and root surface areas. Additionally, regular coppicing would have exposed inner branch anatomy to insect fauna and, depending on the timing of such harvests, could have enhanced breeding success for some avifauna. Natives are also known to have manually controlled gall-forming insects to prevent stem damage. Rotation of harvest areas would have led to a combination of unmodified (temporarily fallow) and more intensively managed patches. While this is a poorly studied aspect of community ecology, these themes may be worth incorporating into restoration practice as other research is advanced in these areas (e.g., Anderson 1999, 2005; Striplen 2005).

Values of the willow lands

As one of the more prominent features of local historical landscapes, willow groves were notable for their remarkable size, associations with freshwater marsh and perennial ponds, and range of cultural and ecological functions. In addition to providing important resources for indigenous peoples, the willow lands also played a cultural role in the early American era, serving as social centers for local gatherings. Mylar ([1929]1985) recalled "camp-meetings in the willow grove over near old Gilroy" in the 1860s, likely referring to either the small grove northeast of Old Gilroy or the larger one to the south. On their drier margins, and in summer months, willow groves were surprisingly accommodating to human social activity. Throughout the Bay Area, historical willow groves were sculpted into shaded, idyllic landscapes, such as Willow Grove Park in Berkeley (Cianciarulo 2001) and the San Lorenzo Grove, which was described as "The Picnic Paradise of California" (Grossinger and Brewster 2003). Willow groves can provide aesthetic and recreational functions in park and reserve design, in addition to their ecological benefits.

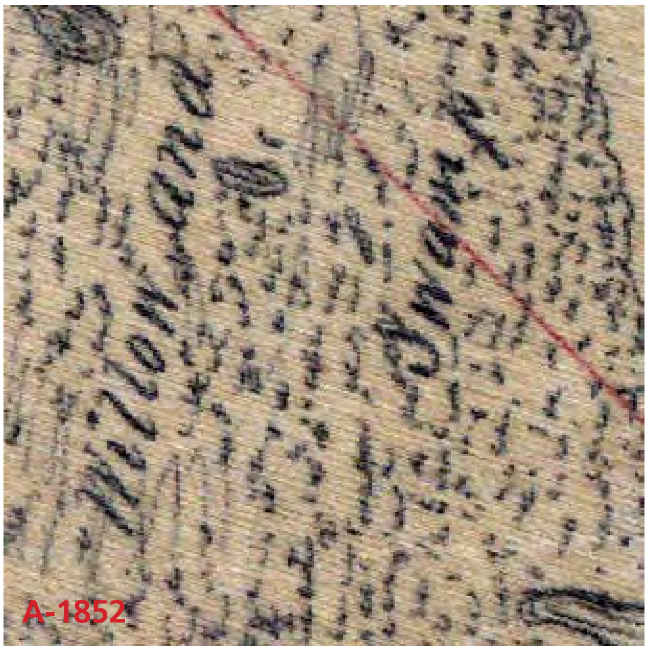
The restoration of willow lands is increasingly being considered because of the wide range of species support functions these broad riparian areas can provide, particularly when part of a surrounding landscape context including perennial wetlands and seasonally flooded meadows. Mature groves had a complex canopy structure that included large trees up to 15 m (50 ft) tall and lower, younger growth. Arroyo willow was the characteristic, dominant species, but sources also suggest the presence of cottonwoods and alder (e.g., Herrmann ca. 1880(?)). While the groves were consistently described as "dense thickets" with understories of blackberry and wild rose, historical accounts also indicate openings, which were used as refuges by both cattle and people (Cooper 1926, Brown 2005).

While willow groves were removed throughout the county relatively early, similar habitats in other areas are well recognized for their benefits for a wide range of bird species. For example, Evens (1993) describes over 80 species of birds that have historically used one of the few significant regional remnants – the Olema Marsh, a large alder-willow thicket in the Point Reyes area. Similarly, the small, recovered willow grove at the South County Wastewater Authority Treatment Plant is well valued by local birders for its ecological functions. In the Santa Clara Valley, historical willow groves probably supported yellow billed cuckoo (*Coccyzus americanus*) and willow flycatcher (*Empidonax traillii)* before they were removed in the late 19th century (Bousman 2007). Local avifauna that would likely benefit dramatically from the restoration of willow grove-floodplain wetland mosaics include yellow warbler *(Dendroica petechia)*, yellow-breasted chat *(Icteria virens)*, Swainson's thrush *(Catharus ustulatus)*, common yellowthroat *(Geothlypis trichas)*, and possibly Wilson's warbler *(Wilsonia pusilla;* Rottenborn pers. comm.). Many of these species have experienced precipitous local declines as these habitats have been removed (Bousman 2007). In addition, these areas would be expected to support a wide range of amphibians.

Least Bell's vireo habitat and willow groves

Willow grove restoration might also play a significant role in the recovery of least Bell's vireo. A state and federally endangered species, least Bell's vireo has been found sporadically in recent years along lower Llagas Creek (Padley 2001, Rottenborn 2007) – the first observations of local breeding attempts since 1932. Breeding habitat for these songbirds is often dense, early/mid-successional riparian thickets (Goldwasser 1981, Franzreb 1989). Accordingly, the recent sightings were associated with the dense, relatively young willow vegetation currently present within the modern flood control channel. The presence of the species has precluded the periodic removal of sediment and vegetation for the maintenance of channel capacity (Presley pers. comm.).

The return of the species to south Santa Clara Valley, the northern extent of its range outside the Central Valley, has raised questions about its historical and potential future habitat. Prior to agricultural drainage efforts in the second half of the 19th century, it is likely that the broad willow grove-freshwater marsh complexes at the downstream ends of Uvas-Carnadero, Llagas, and Pacheco creeks provided highly suitable habitat for least Bell's vireo. Whether these habitats supported vireos in any abundance is unknown; there is only a single historical record from Santa Clara County, though perhaps the highest-quality habitat was destroyed before significant ornithological attention was paid to the Pajaro River valley. The current habitat differs in that the in-channel willow corridor is quite narrow and isolated from other wetlands (fig. 5.16).



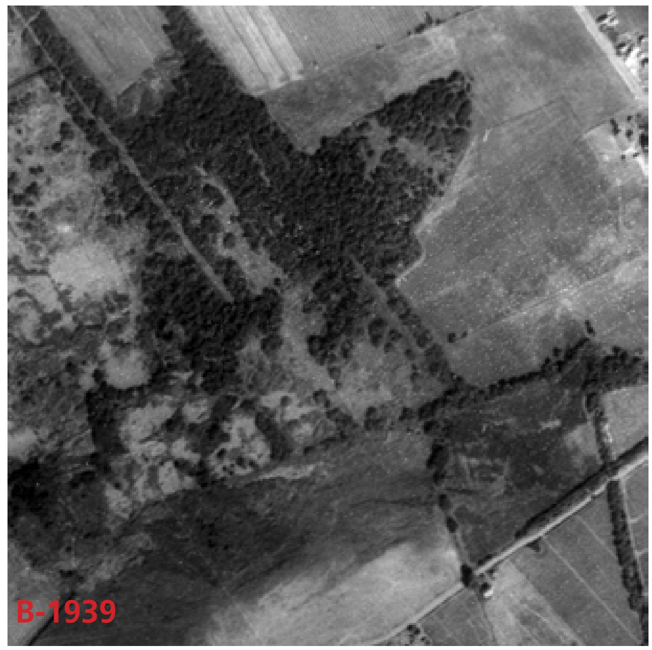


Figure 5.16. The history of the "Willow and Tule Swamp" at the downstream end of Llagas Creek can be seen in this series, starting with McDonald's ca. 1852 map. This map shows willows (hatch marks), freshwater marsh (parallel lines), and ponds (concentric circles). Independent surveys along the red grant line confirm these features. Remnants of the willow grove are still visible in 1939; these were subsequently cleared from the area as part of continued agricultural expansion and the construction of the South County Regional Wastewater Authority Treatment Plant and the Llagas Creek flood control channel. In recent years, willow thickets have returned within the flood control channel (a) and the south pond of the wastewater treatment plant (b). (A: McDonald 1852(?)b, courtesy of The Bancroft Library, UC Berkeley; B: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz; C: USDA 2005, courtesy of NAIP)

In other regions, especially wide (greater than 250 m/820 ft) riparian areas have been found to have disproportionately high vireo population densities (Kus 2002). The expansive historical willow groves, which were 500-1000 m (1,600-3,300 ft) wide with connectivity to perennial ponds and freshwater sloughs and marshes, likely provided excellent habitat. With the rapid loss of the agriculturally valuable willow lands after California statehood, most of this habitat disappeared by 1900. Contemporary willow thickets along the Llagas and other channels are generally narrower than 50 m (160 ft).

The vireo observed nesting in 1932 was found "near Sargent, Santa Clara County" in a willow tree within "a dark thicket" (Unglish 1937). This nest could have been in the riparian forest along the Pajaro River or in the remnant patches of the Carnadero willow grove near Sargent (which are visible in 1939 aerial photography, especially along Tick Creek).

As southern California populations of least Bell's vireo continue to increase in response to habitat restoration and cowbird management, the number and frequency of pioneering vireos in the northern part of the species' historical range are expected to increase. The successful recovery of a breeding population of least Bell's vireo in south Santa Clara Valley appears to be hindered by the lack of suitable breeding habitat and likely by high levels of nest parasitism from cowbirds (Rottenborn 2007). Given the historical prevalence of broad willow thicket habitat in the area, and the accidental recovery of several small groves in recent decades, it is possible that vireo habitat could be significantly expanded in the near future. Successful restoration of broad willow forest-freshwater marsh mosaics would establish habitat of better quality than the narrow patches within the Llagas Creek flood control channel where vireos have recently occurred. Nest parasitism by cowbirds might also be reduced by increased habitat patch sizes with concomitant reduced edge effects, though direct control would likely be needed given the abundance of cowbirds in the Pajaro River valley. Habitat restoration and cowbird control have been effective strategies for least Bell's vireo recovery in other regions (Brown 1993).

While least Bell's vireos place their nests in dense, low vegetation, a structurally diverse canopy provides the highest-quality foraging habitat, and nests are often placed near canopy openings (Kus 2002). As a result, the habitat mosaic of early- to mid-successional riparian forests provides the highest-quality breeding habitat. Shading by older trees may inhibit the development of a dense understory, potentially relegating the highest-quality habitat to forest edges. Ideally, willow grove restoration would be part of re-creating broader floodplain areas – such as through levee setback along lower Llagas Creek – so that habitat mosaics and disturbance regimes are established (PWA 2008, Rottenborn pers. comm.). Where levee alignment cannot be adjusted, however, off-channel willow grove habitat such as that currently developing in the South County Wastewater Authority Treatment Plant could also benefit the species along with a number of other riparian-associated birds, such as yellow warblers, yellow-breasted chats, and Swainson's thrushes. In addition, a sediment/vegetation maintenance regime within the Llagas Creek channel that maintains a mosaic of young and middle-aged riparian habitats may be of greater benefit to least Bell's vireos (while increasing channel capacity for flood control) than avoiding alteration of these channels altogether.

The large size of the historical willow groves means that there are many potential sites for reintroducing significant portions of the groves within their historical extent. Willow grove restoration could be considered on lower Llagas Creek, lower Pacheco Creek and San Felipe Lake, and on Carnadero Creek, potentially as part of the wetland restoration at the Carnadero Preserve. Willow grove restoration at the latter site could reestablish habitat in the vicinity of the vireo nest observed in 1932.

San Felipe Lake

While San Felipe Lake was historically part of a broad floodplain wetland mosaic, it now is primarily an isolated pond, with relatively small fringes of wetland and riparian vegetation. Nevertheless, the Bolsa de San Felipe is recognized as an Audubon Important Bird Area (Cooper 2004). Historical data indicate that the lake was bordered by about 1,000 ha (2,500 ac) of freshwater marsh and a surrounding array of willow groves and alkali meadow. Historical evidence such as the size of the lake, the extent of freshwater marsh, and artesian conditions suggests that groundwater was consistently very close to the ground surface – even higher than current levels (generally within 4 ft/1.2 m; PWA 2008).

There are indications that drainage efforts reduced the depth and duration of inundation in the lake as early as the late 19th century. After the completion of Millers Canal in 1874, willow groves occurred much closer to the lake than they were mapped by Healy in 1858. While these differences could possibly be due to surveyor variability or natural dynamics, the apparent trend continued in the early 20th century. No significant riparian vegetation could be seen on the lake's eastern margin in an 1895 landscape photograph (see fig. 7.28), but by 1939, willows had colonized the lake's east side, a general pattern that persists today (see fig. 5.9). Additionally, intensive cattle grazing has limited the growth of emergent freshwater marsh vegetation where conditions remain otherwise suitable (PWA 2008).

> *"Thousands of geese, sandhill cranes, plover, and curlew darkened the air at intervals"*
>
> – SHAW 1857(?), DESCRIBING THE SOAP LAKE FLOODPLAIN

With its surrounding wetlands intact, San Felipe Lake supported a greater number of species, and in larger populations than are currently observed. For example, a number of fish species associated with floodplain wetlands have been extirpated from the Pajaro River watershed, such as thicktail chub *(Gila crassicauda)*, tule perch *(Hysterocarpus traski)*, and Sacramento perch *(Archoplites interruptus)*; these were all found in San Felipe Lake (Smith 1982, Gobalet 1990, Hildebrandt and Mikkelsen 1993). In fact, thicktail chub, a now extinct species associated with floodplain wetlands, was specifically reported from "Soap Lake" (Miller 1963). In 1860, the *Daily Alta California* stated that in the "Lake of San Felipe" (which they note is "commonly called Soap Lake") there is a popular local fish for sportsmen: "A very good fish called Soap Lake Trout, a kind of perch" (Milliken n.d.). The lake was also an important source of fish for the native people for centuries prior to contact (Fages and Bolton 1911, Crespí and Bolton 1927, Hildebrandt and Mikkelsen 1993).

The areas around the lake were also considered the "best snipe ground in state" (Daily Alta California 1860, in Milliken n.d.) and the value for waterfowl was well-recognized:

> … flocks of wild geese and brant, cleaving the air with their arrow-shaped lines, descended to their roost in the meadows. On their favorite grounds, near the head of Pajaro River, they congregated to the number of millions, hundreds of acres being in many places actually hidden under their dense ranks. (Taylor 1850)

> . . . several good-sized sheets of water, notably the Soap lake, are covered with wild fowl of all kinds. (Munro-Fraser 1881)

> "Several sportsmen from Hollister and Gilroy tried their luck at shooting last Sunday, in the vicinity of Soap lake. H. Frutig led the score at 70, Geo. Eustice and D.L. Dunham having good records at 60. About 300 birds of different kinds were bagged." (Hollister Free Lance 1886a)

With the recovery of floodplain slough and wetland habitat, species such as tule perch and Sacramento perch could potentially be reintroduced. Such range expansion could be desirable given the decline of the species and the limited opportunities for floodplain wetland restoration within the larger region (Smith 1982, Leidy 2007). These habitats could also provide increased support for shorebirds and waterfowl, and food resources for outmigrating steelhead smolts.

Fine sediment storage

The dense clay and adobe soils of the Soap Lake floodplain represent the long-term deposition and storage of massive amounts of fine, stream-borne sediment. These areas served as natural sinks for fine sediment as stream gradients decreased and flows spread widely through marshlands. The Soap Lake floodplain effectively served as a filter for fine sediment, reducing some of the transmission from the upper Pajaro watershed to the river's mainstem. With flows now more confined through channel excavation and/or levee construction and increased disturbance of the watershed, fine sediments tend to be retained within these low gradient channels, reducing channel capacity and necessitating occasional or frequent excavation (e.g., Millers Canal; Hollister Evening Free Lance 1959) and Pacheco Creek (Hanna 1947, 1948(?)). The reduced function of historical areas of fine sediment deposition may have contributed to the apparent infilling of San Felipe Lake and the upper Pajaro River, which each appear to have been substantially deeper historically (Snyder 1912, Smith 1982, Gilroy Advocate 1869b). The fine sediment deposits of Soap Lake wetlands may also be, or could become, sources of fine sediment to the Pajaro River downstream – particularly given any future increases in upstream drainage density and bank erosion. Alternatively, wetland restoration in these areas could help attenuate fine sediment transport downstream, providing benefits to water quality and fish habitat.

Natural flood protection

The seasonally flooded floodplain areas of Soap Lake are recognized as providing natural attenuation of flood peaks for the lower Pajaro River (Stimson 1944, RMC 2005). Minimizing the extent of human settlement, infrastructure, and development susceptible to flooding reduces the risk to human safety and property without expensive flood protection infrastructure. Many parts of South Valley are already extensively developed and require such infrastructure approaches, but some areas may be suitable for natural flood protection approaches (RMC 2005). Naturally ponded areas can limit the height of downstream flood peaks by delaying the contribution of local runoff to peak flows; this was recognized by flood control engineers designing the current generation of South Valley drainage systems (USACE 1975). Seasonally flooded wet meadows and alkali meadows that still provide some peak flow attenuation could be reconnected to the floodplain to maintain and/or enhance such functions, in addition to the associated ecological values. This approach to reducing flood risk could have particular benefits for the Pajaro River because of the importance of the Soap Lake floodplain (RMC 2005), but there may be a number of other potential areas, as evidenced by the map of historical wet/alkali meadows.

Regional distribution

While wetlands were a major component of the south Santa Clara Valley landscape – representing a third of the study area – they occupied distinct landscape positions and were not evenly distributed through the region. The vast majority of the region's wetlands were found within the Soap Lake floodplain — the several mile wide lowlands bordering the Santa Clara-San Benito County line. Except for wet meadows (which were found in occasional lowlands to the north) nearly the entire extent of all other wetland types was found within this contiguous array of wetland mosaics occupying the bottomlands watered by the Uvas-Carnadero, Llagas, and Pacheco creeks.

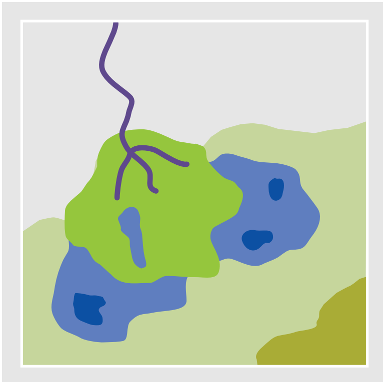
Because of both this naturally restricted distribution and the subsequent urbanization of lowland areas throughout the Bay Area and Central Coast, the Soap Lake area has unusual potential for large-scale wetland restoration.

From a regional perspective, the Soap Lake floodplain likely has the highest restoration potential for non-Bayland wetlands within Santa Clara County and is one of the most important sites in this regard within the nine county Bay Area. A number of local planning efforts have recognized these values (e.g., RMC 2005, Jones and Stokes 2006), but restoration concepts have only begun to be discussed (PWA 2008).

Landscape trajectories

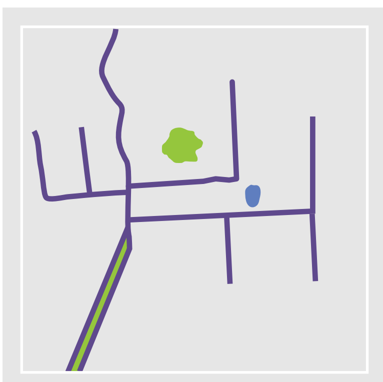
The wetlands of south Santa Clara Valley experienced particularly rapid change following statehood. Among local habitats, the rate of change was probably only exceeded by the invasion of native grasslands during Spanish colonization and the harvest of redwoods in the 1850s. Because of the high value placed on agricultural lands in the second half of the 19th century, and the concomitant need for drainage, most of the freshwater marshes and willow groves areas were severely reduced in extent by 1900.

Drainage systems have continued to expand during the 20th century. However, intensive development has been limited in wetland areas due to the dense soils, alkali conditions, depressional landscape position, and associated flooding. These factors and the return of high water tables in recent decades suggest that significant elements of the historical wetlands landscape could potentially be restored in coming decades (fig. 5.17).

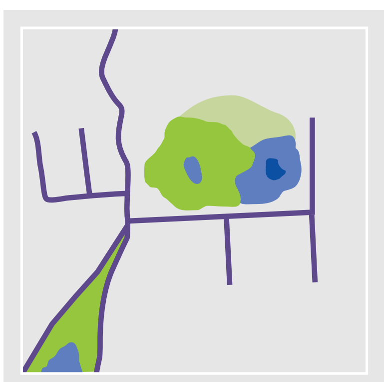


Circa 1800: Willow groves, freshwater marshes, perennial ponds, seasonally wet meadows, and alkali meadows form complex mosaics of wetland habitat. Small sloughs, not shown, spread through the wetlands.

Pre-World War II: Most of the wetlands have been drained for agriculture. Remaining wetlands are impacted by grazing.



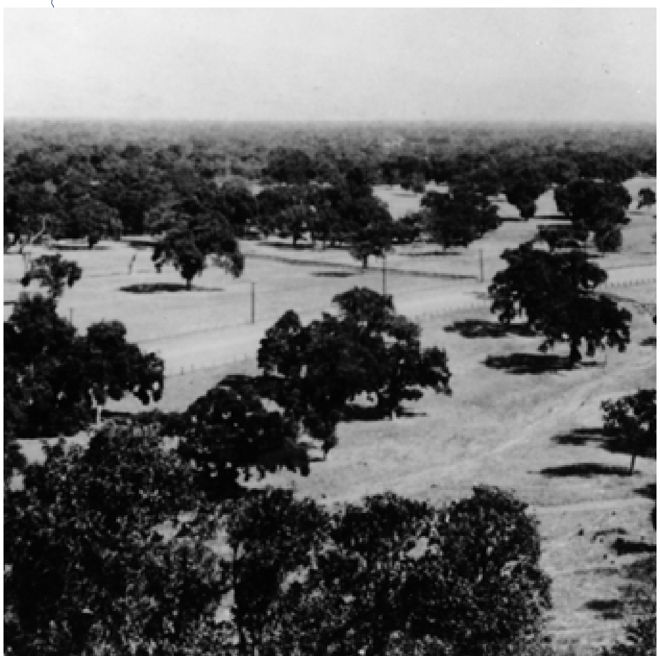
2008: Drainage networks have continued to expand and only small wetland remnants remain. Some agricultural ditches have been replaced by larger engineered channels which have been colonized by willows.



Conceptual Restoration Model: With high groundwater levels, wetland mosaics could be re-designed in dedicated areas to provide flood capacity and support ecological functions. Setback levees could allow natural wetland mosaics to form.

Figure 5.17. Wetland mosaics on the lower reaches of streams: conceptual model of landscape trajectory.

6 OAK SAVANNAS AND WOODLANDS



Above. 19th century view of South Valley oaks.

Below. A South Valley oak in the contemporary landscape.

OAK SAVANNAS AND WOODLANDS

Oak woodlands and savannas once dominated much of California's inland valley floors, including the south Santa Clara Valley, providing critical habitat for a diverse range of native plant and animal species. The acorn woodpecker (*Melanerpes formicivorus*), white-breasted nuthatch (*Sitta carolinensis*), oak titmouse (*Baeolophus inornatus*), and Pacific pallid bat *(Antrozous pallidus pacificus),* along with over 330 vertebrates, can be found living in these habitats. Researchers have recognized that oaks play a central role determining ecosystem function in these inland valleys, providing essential food resources, nesting canopies, shaded understory plant communities, and other services (Mahall et al. 2005). The loss of the dominant species of these oak lands, the once common valley oak (*Quercus lobata*), raises concerns for the health of the systems they support.

Despite losses in range and density (Sawyer and Keeler-Wolf 1995), valley oaks remain iconic within the cultural landscape of inland valleys as majestic trees often revered as part of the local natural heritage. In just the period of 1945 to 1973, estimates indicate that rangeland "improvement" (clearing), agriculture and urban development in California have led to the loss of 1.2 million acres of oak woodlands and savannas of the original 10 to 12 million (Bolsinger 1988). Much greater losses occurred prior to 1945 (Mahall et al. 2005). The remaining areas are largely unprotected, making conservation key to the preservation of these communities (Bolsinger 1988, Davis et al. 1998). Not surprisingly, agricultural and urban development seeking rich soils and flat lands come in direct conflict with oak woodlands and savannas (Griffin 1973). The result of this conflict is evident from the relative scarcity of oaks in the south Santa Clara Valley today.

Statewide trends show a steady decline in density and lack of oak recruitment over the last century, which raises concerns of reproductive isolation (Brown and Davis 1991, Davis et al. 2000, Sork et al. 2002). Oak mortality has also been linked to more indirect effects due to land use change, such as declining groundwater tables, making it more difficult for taproots to sustain trees through the summer drought months (Griffin 1973). Studies raise the concern that natural rates of oak regeneration may be less in some areas than the rate of loss due to added pressures of land use conversion and climate change (Sork et al. 2002, Mahall et al. 2005). Such evidence makes conservation and restoration of these landscapes and the ecosystems they support a priority.

Despite these concerns, relatively little is known about the finer scale pre-European contact characteristics of California's valley oak woodland and savanna landscapes – a scale important for restoration efforts (Brown 2002). Studies of the historical density and distribution of oak lands have rarely quantitatively addressed periods prior to the mid-1900s, when aerial photography becomes available. Such a long-term perspective is important because while the most intensive local urbanization occurred following World War II, European land use (including ranching as well as orchards and other row crops) has been a dominating force in the south Santa Clara Valley since the mid- to late-1800s. This study uses a range of data sources from the 1770s to contemporary times – with particular attention to mid-1800s surveys and maps – to assess the historical spatial patterns of valley oak lands and historical changes over that time. We use early settlement-era sources, including local maps, U.S. General Land Office (GLO) surveys, county surveys, narrative descriptions, and landscape photography, to provide valuable evidence for reconstructing the pre-contact landscape. Informed by these sources, the later (mid-1900s) aerial photography provides an additional valuable dataset.

With these data from the early settlement period, supported by information from the early 20th century, we endeavored to document the historical density and distribution that characterized valley oak landscapes as a basis for future landscape conservation and restoration efforts. Mapping historical oak density distribution is an important component of restoration efforts for several reasons. Refining our knowledge of ecologically suitable areas and physical factors limiting oak distribution through historical analysis could improve the likelihood of success of restoration and regeneration efforts. Restoration at the landscape level is important to help ensure genetically viable communities and successfully support oak-dependent species. Given the competing demands for fertile valley land, spatial patterns of density and distribution are critical pieces of information for designing a conservation plan and a planting template. As valley oaks are reintroduced into areas within their historical range (or anticipated future range under climate change scenarios), such information can guide how woodlands and savannas are reincorporated into our contemporary landscapes.

METHODS

Our analysis of oak savanna and woodland habitat uses a variety of sources and methods in order to benefit from the broad but heterogeneous range of historical data available (Grossinger et al. 2007a). We took an integrated approach that made use of both quantitative data and textual descriptions, each with their own level of accuracy and uncertainty. The methods used in this assessment reflect the desire to incorporate quantitative data such as GLO survey notes, and yet not exclude other, more qualitative data that nevertheless have valuable information about historical oak patterns which is not otherwise available. The way we used these sources is outlined below.

Our estimates of historic stand density in oak savannas and woodlands rely primarily on GLO surveys, with other early sources used to independently corroborate or adjust our initial calculations. To map distribution beyond the GLO survey lines, we used all other available historical data sources, most notably the relict 1939 canopy-sized (> 15 m/50 ft) valley oaks visible in aerial imagery and their correlations with soil type and texture (Davis et al. 2000). We also used a number of earlier historical records that illustrate oak patterns such as landscape photography and textual material. We developed a several step process to integrate and inter-calibrate data from different eras to illustrate changing oak landscapes (table 6.1).

General Land Office data

An important source for reconstructing historical vegetation patterns is GLO survey data. Although researchers note that these surveys were not intended as ecological studies, and thus should be used with care, they nevertheless contain valuable and extensive information on historical vegetation, soils, and water features (Collins and Montgomery 2001). While only rarely employed in studies of valley oak density and distribution (Bloom and Bahre 2005, Brown 2005, Dawson 2006), the field notes from these surveys have been used successfully in many projects in the Midwest and Northwest to determine historic forest stand densities (e.g., Buordo 1956, Manies 1997, Radeloff et al. 1999, Sickley et al. 2000, Collins and Montgomery 2001). The surveys have allowed researchers to place data at a level of accuracy and consistency rarely available from other sources of this era.

Initiated by the U.S. Continental Congress's Land Ordinance of 1785, the GLO's Public Land Survey provides some of the most detailed descriptions of landscape and vegetation prior to the extensive environmental changes following European contact (Buordo 1956). The survey stemmed from the U.S. government's desire to populate the West and pay off debt through assigning public land to homesteaders or selling the land to timber, railroad, and mining interests. Systematically conducted from

Table 6.1. Available sources for different time periods.

Data Time Frame	Era	Sources
1770s to 1830s	Spanish	Early explorers' journals
1830s to 1860s	Ranching and early agriculture	GLO bearing tree and descriptive data, travelers accounts, land grant case testimony and maps
1870s to 1910s	Agricultural intensification	Landscape photography, local histories
1939	Pre-World War II	Aerial photography
2005 to 2008	Contemporary	Aerial photography, groundtruthing

Ohio to the West coast, the GLO surveys established the township and range lines we are familiar with today. They reached Santa Clara County in 1851, and continued in the area until 1884.

The GLO surveys divided public land holdings into six mile square townships with 36 one mile square sections. This was done by first creating two principal lines: an east-west baseline and a north-south principal meridian. The township and range lines were then drawn parallel to these established lines. The section and township corners thus ideally form a spatial dataset of regularly spaced points across the landscape at a resolution as fine as the quarter-section (0.8 km/0.5 mi). However, many areas in California lack a complete network of inner township section lines as a result of the U.S. government honoring the Mexican land grant holdings, many of which were located in the rich coastal valleys of California, including the south Santa Clara Valley (White 1991). As a consequence, GLO surveys in the valley include those for the principal township and range lines as well as the land grant lines, but lack section subdivision surveys. The confirmation surveys of the irregular land grant boundaries were performed by official GLO surveyors, but instructions were often less strictly followed, resulting in more irregular data.

We obtained GLO surveyor notebooks from the microfilm archives at the Bureau of Land Management Office in Sacramento, CA. This included the official surveys for the Mexican land grants.

We adapted methods developed by the Forest Landscape Ecology Lab at the University of Wisconsin-Madison that use Geographic Information System (GIS) to store, display, and analyze the GLO data (Manies 1997, Radeloff et al. 1998, Sickley et al. 2000). One of the primary benefits of the ArcMap (ESRI) form developed by the Wisconsin group is its ability to place the survey points efficiently and accurately within a contemporary spatial coordinate system (although only as accurately as the lines layer upon which the points are placed) based on distances given in the field notes. In addition, this system efficiently establishes a database that can be easily used in subsequent analyses both in and out of a GIS environment.

Our oak analysis makes use of the bearing tree information as well as more qualitative descriptive notes, which the GLO instructed surveyors to obtain along with other data as they passed through the landscape. To establish the location of section corners and half mile points ("quarter sections"), surveyors noted up to four bearing trees, recording the species, diameter, azimuth, and distance from the points. If no trees were available within "convenient and suitable distances," surveyors were instructed to establish a mound and trench (GLO 1871). Thus, the absence of trees gives evidence for areas of sparse tree coverage. Quantitative information available from these surveys include species, trunk size, and distances to bearing or witness trees (used to establish survey corners) from survey points, the latter of which have been used to map density of tree cover (Radeloff et al. 1999).

Some researchers have noted a possible bias toward long-lived trees or trees with easily marked bark (Radeloff et al. 1999, Collins and Montgomery 2001). However, we believe that a preference to long-lived species such as oaks would not have a significant impact on our analysis. We also note evidence that surveyors were, in fact, responsive to the actual closest trees: while oaks are commonly recorded in some areas, in areas shown by other maps as willow swamps, the GLO surveyors used willows, while sycamores were recorded in sycamore alluvial woodlands along local streams.

In addition to bearing trees at section corners and quarter sections, GLO surveyors also noted trees they encountered in the path of their survey lines, referred to as "line" trees. The relative frequency of their occurrence also suggests density trends, although we used these data solely for visual comparison and corroboration given the limited number of such trees. As part of their field notes, surveyors described the land cover at every mile point, including general remarks on timber characteristics of the previous mile such as "scattered oaks," "oak groves," or "open plain." Such descriptions are useful when attempting to extrapolate density and distribution at a larger landscape scale.

Other data sources

We obtained copies of Spanish explorers' journals, traveler accounts, local histories, and landscape photography from local libraries and historical societies. We acquired confirmation and diseños and reviewed text of Mexican land grant cases at The Bancroft Library. The land grant maps and other early cartographic sources were also used to corroborate general density differences and refine the distribution of oak stands. Like the surveyor descriptions, historical narrative accounts provide additional qualitative evidence of pre-settlement density and distribution characteristics of oak savanna and woodland habitat. Where possible, we incorporated these accounts into the GIS. Based on density and descriptive relationships established through the GLO data, narrative accounts of oak woodlands and savannas helped us classify the habitat, particularly in areas with little quantitative data. Landscape photography provided visual representations and also helped us understand spatial clustering and patterns within the oak habitats. Although density calculations could not be performed, these sources show presence/absence and relative density, allowing for calibration of the GLO dataset. Eighteenth and early 19th century sources, while limited, helped assess whether or not GLO data reflect significant changes to oak distribution and abundance since Spanish contact.

We used historical aerial photography taken by the USDA in 1939 to inform our early contact-period picture as well as analyze the presence of oaks just before World War II. Most importantly, this is the earliest available source showing a complete distribution of oaks within the study area. The images were orthorectified using the Leica Photogrammetry Suite module of ERDAS Imagine 8.7. We digitized probable canopy sized valley oaks (> 15 m/50 ft), based upon their distinctive size, shape, and groupings (Brown 2002, Sork et al. 2002, Mahall et al. 2005) and compared this dataset to contemporary 2005 NAIP imagery, noting the trees that remained in 2005. We identified 1,976 trees from the 1939 imagery as "probable valley oaks." Although research has used the rings of root rot in orchards to digitize locations of historic oaks (Brown 2005), we did not find significant evidence in our aerial photography. We believe our digitizing is a conservative estimate of the population, as individual trees are often difficult to distinguish from one another in urban areas or when canopies overlap. However, given that comparisons to pre-contact and contemporary distribution are based on relationships established from this dataset, we do not expect this underestimation to significantly affect observations of change over time and estimated areas of local losses.

Contemporary soil survey data for south Santa Clara County (USDA [1972]2007) provided our basic mapping units. We related soil types and textures to the presence and absence of our mapped 1939 relict oaks to determine likely areas of oak woodland and savanna. We also compared the distribution of 1939 oak trees to the distribution of wet and alkali meadows, which were acquired primarily from soils data (see Chapter 5). We also consulted the Vegetation Type Map collection (Wieslander 1935), which consists of vegetation maps and plot data of overstory and understory vegetation across California. However, we found that most of the valley floor had been mapped as cultivated, and the few related plot data from the surveys were restricted to the margins of the study area.

Estimating pre-contact stand density and canopy cover

To estimate pre-contact stand density from our GLO bearing tree database, we applied formulas relating stand density and distance from a given point (our section corners) to the nearest tree (Cottam and Curtis 1956, Radeloff et al. 1999). Density (*d*), the number of trees per unit area, is the inverse of the mean area, the area per tree. The square root of the mean area (*M*), or the distance between trees, is equal to the average of the distances from a given survey point to four trees, one in each quarter (quadrant). Based on this relationship, researchers have shown that the distance to the nearest tree from a point theoretically equals 0.5 times the square root of the mean area ($0.5\sqrt{M}$) (Cottam and Curtis 1956). However, Cottam and Curtis (1956) found that a factor of 0.6 improved their density estimation. Using representative stands from historical aerial photography of both Santa Clara and Napa counties to reproduce the point centered quarter method, we determined that the factor best representing the actual density of these stands was 0.53. Using this correction factor with the relationships discussed by Cottam and Curtis (1956), we calculated the density at each survey point using the equation, $d = \frac{1}{(1.89Q_1)^2}$ where Q_1 is equal to the distance in meters to the nearest tree. Even though this meant reducing our tree dataset from 88 oaks to 46 oaks, we determined that using only the nearest tree, rather than all bearing trees at each data point, would be a more accurate estimation of density. Had we used all bearing trees, the average of all tree distances about each point would have been biased toward a higher density, as four bearing trees were rarely noted in the surveys. Where no bearing trees were available, we estimated a maximum possible density using the maximum distance surveyors were willing to travel to obtain a bearing tree as the Q_1, which based on the dataset was 185 m (600 ft).

As an initial exploration of the data, we calculated an average density for all GLO survey points with bearing trees. The limited quantity of GLO data and its high variability prevented us from interpolating density levels spatially from the point data. However, these data provided quantitative evidence for large-scale density patterns across south Santa Clara Valley, which were then refined using additional data sources. Subsequently, these density data, which we averaged for the mapped oak woodlands and savannas, were used to estimate historical numbers of oaks. Our density analysis included all oak species, both for practical purposes and because all oak species together create the function and appearance of the woodlands and savannas.

To translate these density data into mapping units, we established oak habitat types, based on classification systems of Allen-Diaz et al. (1999), the Federal Geographic Data Committee (1997), and Sawyer and Keeler-Wolf (1995). We used three dry land habitat types to indicate a range of oak densities: grassland, savanna, and woodland (table 6.2). Although Allen-Diaz et al. (1999) defined oak savanna as canopy cover less than 30%, we used a cutoff of 25% to match the Federal vegetation definition of woodland systems, with canopy cover between 25 and 60% (FGDC 1997, Allen-Diaz et al. 1999). Although these contemporary classifications do not define a savanna class between grassland and woodland, we were interested in highlighting the presence of valley oaks at a finer resolution for percent canopy covers less than 25%. We used 10% canopy cover as the approximate lower boundary for oak savanna, which has been used in other studies, despite the fact that even lower densities can still function as oak savannas (Davis et al. 2000). Given our dataset and other evidence that live, black, and possibly blue oaks also grew in the valley, these classes were used to define a mixed cover dominated by valley oak, which corresponds to the mixed cover series in modern classification schemes.

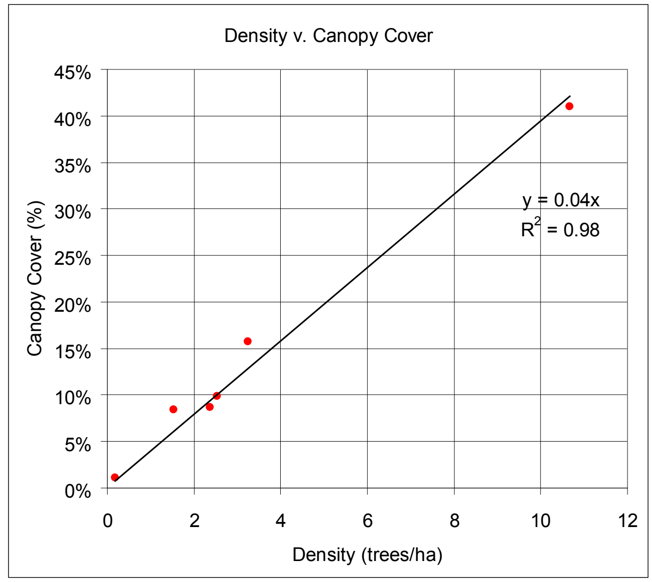


Figure 6.1. Density versus canopy cover for six representative stands using a linear regression with a fixed intercept.

To relate density to our classified habitat types, we estimated percent canopy cover from a linear regression of density and percent canopy cover using six representative stands found in the 1939 aerial photography of the south Santa Clara Valley. These representative stands of 25 to 50 trees were selected visually for a range of densities, where confidence was relatively high in distinguishing individual trees. We drew three possible polygons around the stands, which were averaged to estimate the stand area and capture the uncertainty in defining an exact stand area. Tree canopies were then digitized within each stand. Using GIS, we summarized the stand area, canopy area and the number of trees. We found that the percent canopy cover was equal to 0.04 times the density (trees/ha) (R^2 = 0.98) and used this relationship to roughly estimate the percent canopy cover of the densities determined from the GLO dataset (fig. 6.1). This relationship could vary if trees, on average, were smaller (or larger) in the 1850s than in 1939, so the translation from stand density to canopy cover should be considered only an approximate measure. It should also be noted that adding several higher density stands to the dataset would increase confidence in this factor.

Refining distribution of oak woodland and savanna

We took an iterative approach to mapping the regions of grassland, savanna, and woodland habitat types. We correlated the distribution of relict valley oaks in the 1939 aerial photography with soil type and texture to determine specific soils associated with likely presence

Table 6.2. Mapped habitat types, corresponding modern vegetation class, and percent tree canopy cover.

Habitat type	Modern vegetation class (FGDC)	Canopy cover
Grassland	Temperate or subpolar grassland with a sparse tree layer	0 - 10%
Savanna	Temperate or subpolar grassland with a sparse tree layer	10 - 25%
Woodland	Open tree canopy	25 - 60%

or absence of oaks. Such techniques have been used by researchers to show the importance of soils as a factor in determining valley oak distribution (Davis et al. 2000, Brown 2002, Dawson 2006). For each soil type and texture, we calculated the number of relict 1939 oaks in each soil class using a spatial join in GIS. We followed methods employing a chi-square statistical test to determine whether actual distributions of oaks on soils were significantly different from a random distribution (Neu et al. 1974, Davis et al. 2000). Both positively and negatively correlated soils (confidence level of 90%) were used as the first cut to map probable oak woodland and savanna areas and grassland regions.

> *"... surrounded in every direction, far and near, with golden lakes of wild oats, thickly studded and shaded by the oaks."*
>
> —WISE 1850

Areas of oak woodland were mapped first, by integrating areas around GLO points of high density, descriptions by surveyors and explorers defining denser regions, and early maps depicting groves. We found that these denser woodland areas were consistently described by each source type. Detailed accounts by explorers and surveyors provide a wealth of information that includes both locally specific and regional accounts. Several landscape photographs were also used to corroborate evidence of relative densities suggested by the explorers' accounts, GLO dataset, aerial photography, and soil correlations.

In contrast, we found that savanna regions appear to have more fluid boundaries with grassland regions, so we used early accounts to confirm the basic trends apparent in the distribution set by the soils correlations; however, we rarely found need to modify the extents of these polygons. Data noting the absence of trees were equally valuable when defining the extents of habitat areas. Unmapped areas outside the mapped oak savanna and woodland polygons and other habitat types were assigned to the grassland habitat type.

We also used the extents of selected and digitized wet meadow/seasonal wetland soil types from the USDA soil surveys to confirm areas unlikely to contain oaks. Soils with poor drainage, heavy texture, herbaceous vegetation, or salts and alkali have been found in north Santa Clara Valley to be particularly unsuitable for oaks (Grossinger et al. 2007a). This independently mapped distribution largely matched areas where no trees were found in the GLO surveys. In our mapping hierarchy determined from our mapping confidence levels, the extent of these wet meadow/seasonal wetlands was modified to match our mapped woodland polygons, but was used to define boundaries of our savanna and grassland polygons.

Estimating changes in oak presence

To illustrate the change in oak savanna and woodland habitats over time, we calculated our baseline, pre-contact number of trees by averaging estimated densities of GLO data points that fell within our mapped habitat extents. We used an average of all GLO points outside woodland to define an average historical savanna density and assigned grassland as zero tree density. Contemporary mature trees were mapped by comparing locations of trees in 1939 to 2005 imagery in order to identify corresponding trees. This produced an initial estimate supported by limited ground truthing and does not include new trees established after 1939. A field survey of contemporary trees could greatly improve the present-day estimates.

RESULTS

Stand density and canopy cover

We found evidence that historical stand densities in south Santa Clara Valley were dramatically higher than today and considerably higher than what might be assumed using 1939 aerial photography. The areas of highest density were coincident with large alluvial fans present in the valley.

Our mapping suggests that oak woodland dominated the northern Morgan Hill area, while more southerly regions – outside wet meadows – were largely covered by less dense oak savanna or grassland. Within the savanna systems areas of dense groves appear at locally favorable sites, with only the largest and most well defined of these actually distinguished by the habitat mapping.

The GLO tree dataset contains a total of 134 trees with distance information, of which 84% are oaks and 74% are white oaks (assumed valley oaks), located at 58 survey points (table 6.3, fig. 6.2). Based on these 58 points and their associated "nearest tree," we analyzed only the nearest oaks (88% valley oak), of which there were 46, and found an overall average oak stand density of 4.9 trees/ha (2 trees/ac). Based on our regression relationship between density and percent canopy cover, we estimate an average 19% canopy cover for these survey points, which falls within the range of our savanna habitat type class. It is important to note that this value is not a representative average density for the study area, as it does not include points with no bearing trees. For these points where no bearing trees were noted, we calculated a maximum density of <0.1 trees/ha (0.04 trees/ac), or less than 0.5% canopy cover.

Corroborated by other sources, our initial exploration of the GLO data showed a visible break in tree cover between the Morgan Hill area and the rest of the study area, distinguished by points with no bearing trees. Also, 20 of the 30 line trees were located in this northern extent. GLO point density data in the Morgan Hill area have an average of 9.8 trees/ha (4 trees/ac; approximately 39% canopy cover), which falls within the woodland class. This estimate is based on 17 nearest oak trees (82% valley oak; table 6.3, fig. 6.2). When woodland groves identified by other sources were mapped, the average density associated with the 20 GLO nearest oak data points falling within woodland polygons was 13 trees/ha (5 trees/ac), roughly 50% canopy cover. Due to a larger estimated margin of error in the mapped savanna versus grassland and the few data points available, we used all other points (23 points with nearest oaks) in savanna and grassland polygons estimate savanna density, leaving grassland at zero. We found an average of 2.9 trees/ha (1.2 trees/ac) for the oak savanna habitat (a 12% canopy cover) within the lower range of the savanna class. Representative contemporary illustrations of these classes from the study area are limited, but examples are provided from 1939 aerial imagery and recent landscape photographs (figs. 6.3 and 6.4).

Table 6.3. Estimated oak density and approximate canopy cover based on GLO point data showing the average minimum distance to trees from given points. Includes data averaged over the whole study area, the general Morgan Hill region, and woodland and savanna habitats.

	Number of oaks	Average distance to oak (m)	Density (trees/ha)	Estimated % Canopy Cover
All Oaks	46	24.0	4.9	19%
Morgan Hill area	17	16.9	9.8	39%
Woodland	20	14.7	13.0	52%
Savanna	23	31.3	2.9	12%

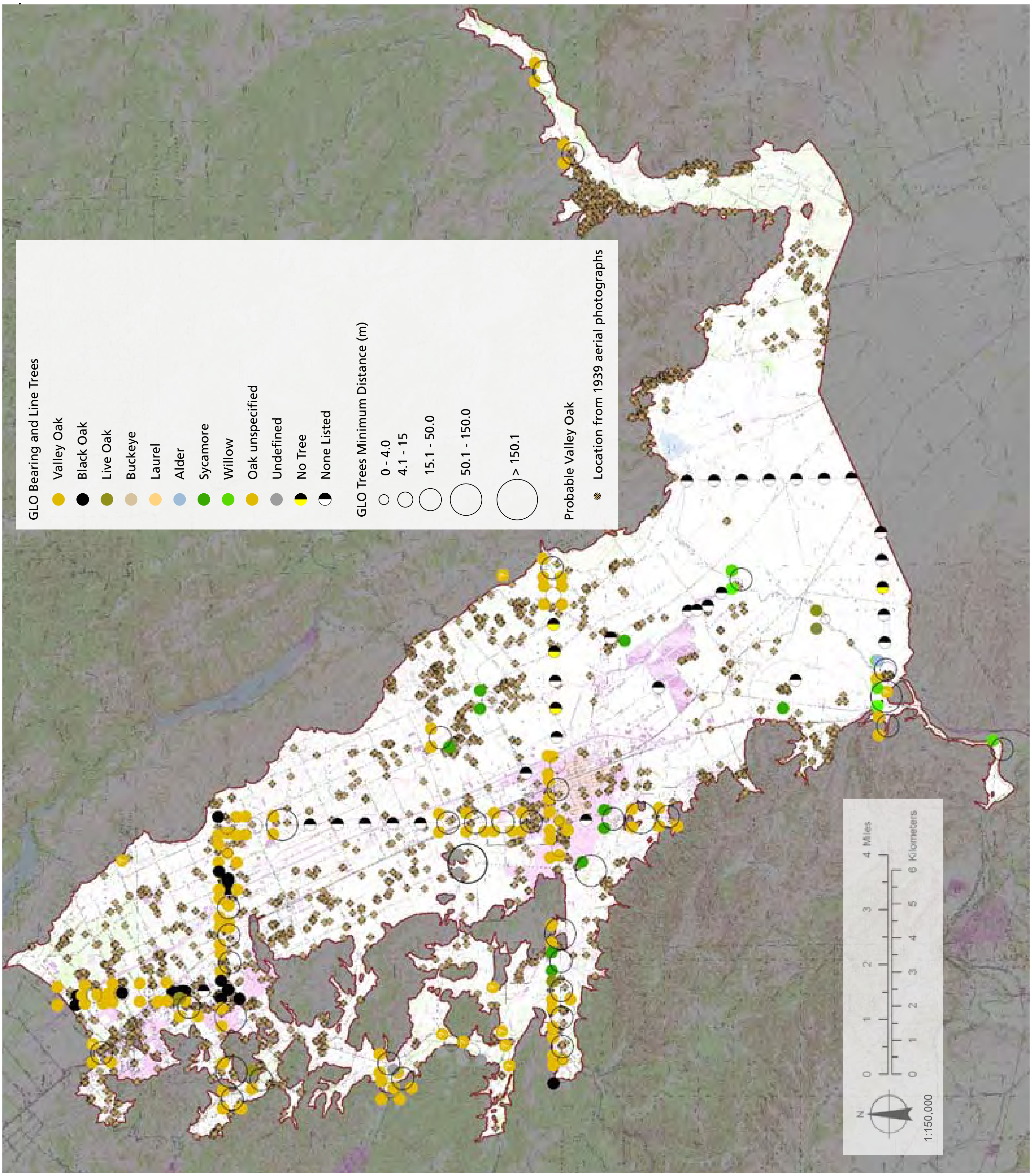


Figure 6.2. Data compiled from mid 19th-century General Land Office surveys (tree species and minimum distance to nearest tree) are shown here, along with valley oaks mapped from 1939 aerial photography (brown stars).

Oaks were clearly distinctive features within South Valley, and many of the earliest sources available highlight the prevalence of oaks and the general character of the woodlands and savannas. Such sources bring historical landscapes to life and provide general corroboration of the GLO bearing tree data. Landscape photography gives a visual sense of densities in places that were not cleared by the time the photographs were taken, while narrative descriptions provide further evidence of the oak woodland and savanna extent and density variations at both local and valley scales.

Based on the GLO data available, we were able to create a crosswalk from descriptive terms to our savanna habitat classification. Textual accounts of "scattered" oaks associated with data points of an average density of 3 trees/ha (1.2 trees/ac) or about 12% canopy cover (within the savanna class). In support of this finding, descriptors such as "scattered timber," "thinly scattered white oak," and "open plain, scattering oak timber" are encountered more frequently in the southern portions of the study area, where we have less evidence of large areas with dense woodland characteristics (Day 1854). Other common terms, such as "grove" or "woodland," supported our classification of woodland habitats, while descriptions of "open plains" were used to classify grassland. (However, these latter terms were not common enough to relate to a specific density.)

The dispersed or scattered nature of savannas, with grass under-story cover, was characterized as having a "natural park-like appearance," while others described the spacing like that of an orchard (Shortridge [1896]1986). In one of the first explorations of the valley in 1772, Crespí (Crespí and Bolton 1927) recalled that "much of it [south Santa Clara Valley] was well grown with oaks and live oaks." In 1776, Anza (Bolton et al. 1930) found the valley a "spacious plain with many oaks and live oaks." A broad view of the valley, most likely from the Llagas area, is captured by one traveller who was "surrounded in every direction, far and near, with golden lakes of wild oats, thickly studded and shaded by the oaks" (Wise 1850). Descriptions also reiterate the heterogeneous pattern suggested by GLO data, indicating that oak savannas did not entirely cover the valley. Geologist William Brewer noted entering a "belt of scattered oaks" in the Pacheco Pass area and a region of oaks south of Morgan Hill that was "four or five miles wide covering the middle" (Brewer [1930]1974).

> Commonly used historical terminology appears to translate into classifications we recognize today.

In addition to determining that "scattered" timber referred to what we would today call oak savanna, we found that denser woodlands were also consistently identified by surveyors, written descriptions, and visual evidence. Indicators of higher stand density included descriptions such as "valley land covered with oak timber," "a heavy growth of oak timber," or "densely timbered" (Thompson 1857a, Harrison ca. 1888). In particular, the terms "woodland" and "grove" appear to have described what was a fairly recognizable or self-evident pattern of higher density areas on the valley floor. Wooded regions shown on maps consistently corresponded to areas reported as woodlands or groves by GLO surveyors. For example, a diseño from the 1840s likely depicts a large oak woodland, or "roblar," in the shape of a fan on the eastern side of the valley across from Morgan Hill (fig. 6.5). Two accounts of this area confirm the feature:

> ...on the eastern side of the valley, is a large area of virgin soil, beautiful level valley land, covered with wide-reaching oaks, ably fine vine land, and is the least populous of all the Gilroy section of country. (Harrison ca. 1888)

> A large body of oak timber... (Day 1854)

Turn of the century landscape photographs from the Morgan Hill area also suggest a high density, corresponding to the high densities calculated from GLO data (fig. 6.6). These data correspond with observations from an explorer “that the timber grew more plentiful and the trees larger” moving north from Gilroy (Manly 1894). Surveyor Richard Howe (1851) characterized an area near Morgan Hill as “low scrubby mossy oak timber,” which still connotes the idea of dense woodland, but perhaps suggests smaller and younger trees. Additionally, a confirmation map drawn from the survey for the Ojo de Agua de la Coche rancho land grant (encompassing Morgan Hill) shows a continuous tree cover across the grant line in this part of the valley (fig. 6.7). The trees in this area correlate with the inactive fan of historical gravelly soils shown by both historical and modern soils maps. While it is difficult to quantify these depictions of the landscape individually, the volume of these data and their close correspondence with the GLO bearing tree data and to each other contributes to a consistent view of the distribution and character of oak savanna and woodland.

We also found evidence for finer scale variation in oak distribution within the general cover classes. While open savanna characterized much of the study area, smaller patches of oak woodland are often distinguishing features within the more sparse savanna setting. Encompassed within a landscape view of “scattering oak timber,” denser zones, or “roblars,” are consistently distinguished in early maps and by GLO surveyors as they

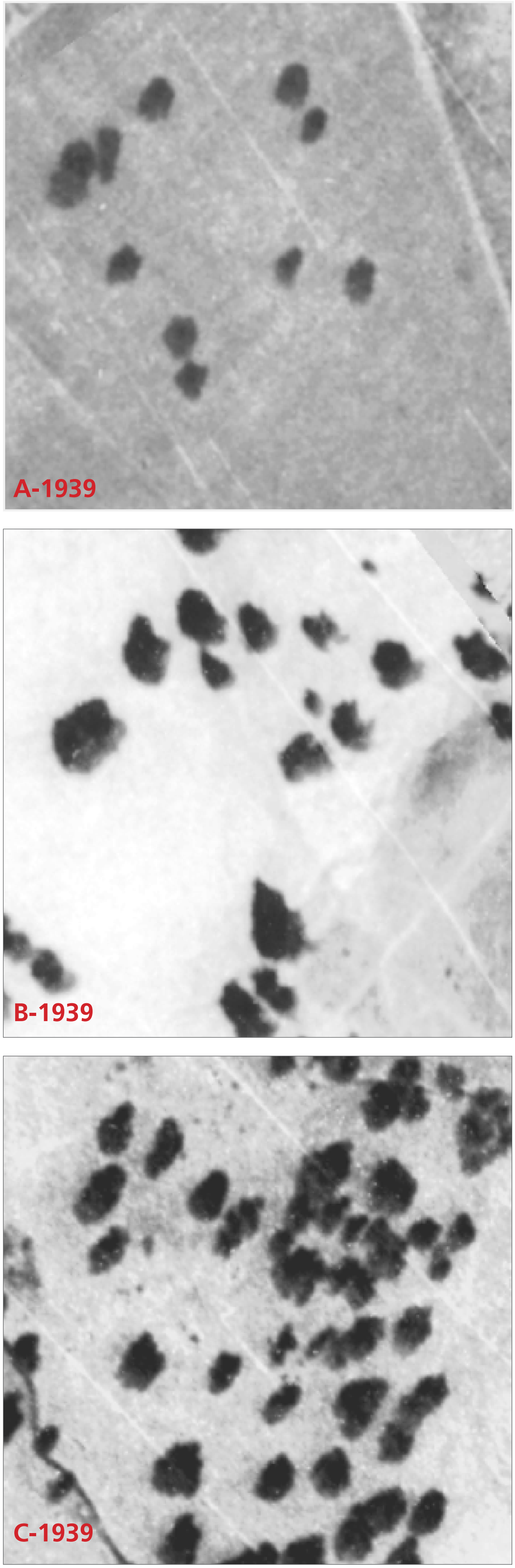


Figure 6.3. Exemplary 1939 aerial photographic views of a grassland (A) with a low but significant valley oak density (1.7 trees per hectare/0.7 trees per acre; 3-5% cover), a savanna setting (B) with 2.8 trees/ha (1.1 trees/ac; 9-10% cover), and a grove or woodland (C) (7.6 trees per hectare/3 trees per acre; 25-30% cover). Each view covers 6.4 ha (16 ac) and is shown at 1:3000 scale. These views also illustrate some of the different landscape patterns possible, from more even distribution to pronounced clumping. Differences in the average size of trees in a given area also result in local variations in the relationship between stand density and canopy cover. (A, B, and C: USDA 1939, courtesy of the Science & Engineering Library Map Room, UC Santa Cruz)

entered or left “groves” (Day 1954). In 1774, explorer Palou summed up this multi-scale pattern:

> ...the plain we were keeping on through was much grown up with white oaks and live oaks, and we came across some patches of thick woods of these same trees. (Brown 2005)

An alternate translation refers to the “thick woods” as “dense groves” (Bolton et al. 1930).

Another account from 1896 referred to the valley in the Gilroy area as “formerly covered with groves of magnificent oak trees” (fig. 6.8; Shortridge [1896]1986). Farther north in 1850, “magnificent clusters of oaks” created “one continuous vista of unexampled beauty” (Wise 1850). We expect that, although we were only able to map the location of several of the most notable small-scale groupings (on the order of 10 ha/25 ac), these small stands or groves were common within the larger savanna setting. Differences in density distribution are also addressed through glades, openings, or “abras” that occur in overall denser woodland areas (Lewis 1850a,

Figure 6.4. Contemporary landscape photographs of valley oak savanna and woodland. The first two images show the same small savanna (7 trees in 0.8-1.2 ha/2-3 ac) from two vantage points. From a distance (A), the relatively wide distance between trees can be seen; a closer view (B) captures the combined effect of the trees despite the wide spacing (generally 50-100 m/160-330 ft apart). In the foreground of C, valley oaks in a savanna setting leaf out in early spring. Clumps of valley oaks can be seen on the valley floor and live oaks are common on the hillside behind. A rare remnant grove of valley oak woodland (D) is found along Highway 152. This is the same site as the 25-30% cover 1939 example in fig. 6.3 (bottom).

Figure 6.5. (Left) Early diseño of the Ojo de Agua de la Coche Grant depicts a fan-shaped oak woodland area on the eastern side of the valley, just south of where Coyote Creek bends northward. The land grant confirmation map of this same land grant depicts widespread trees within the valley. (U.S. District Court, Northern District [184-?]a, courtesy of The Bancroft Library, UC Berkeley)

Day 1854; see fig. 6.13). Thus, while it may be difficult to imagine a continuous expanse of evenly distributed trees at a density of 11 oaks/ha (45 oaks/ac), woodlands at the landscape scale may simply appear as more tightly spaced groves at the local scale. It is easy to imagine early settlers establishing roads, towns and small fields within the trees, but between groves.

Species composition

Of the 182 bearing and line trees recorded by GLO surveyors, 65% were white (presumed valley) oak, 9% black oak, 3% live oak, and 5% unspecified oaks. These data indicate that most of the trees on the valley floor were oaks, and most of those were valley oaks (table 6.4). Black oaks and live oaks were a minor, but significant, component of the oak woodlands and savannas of south Santa Clara Valley.

Virtually all the black oaks are located in the Morgan Hill region, interspersed with valley oaks. Eight of the 17 were recorded as "Red oaks," an eastern species with leaves similar to black oaks. Several narrative descriptions support mixed

Figure 6.6. (Right) Late 19th-century views of the oak woodlands that dominated south Santa Clara Valley near Morgan Hill. (A (Unknown 1892) and B (Unknown ca. 1900c): courtesy of the Morgan Hill Historical Society)


A-1892


B-ca. 1900

Figure 6.7. Trees are indicated continuously along the boundary line of the Ojo de Agua de la Coche land grant on this 1857 map, which crosses the full extent of the valley floor. (Thompson 1857b, courtesy of the Bureau of Land Management)

Figure 6.8. The oak grove west of Gilroy shown on this 1885 lithograph was also noted by GLO surveyor Richard Howe, who recorded "left the woodland" in his 1851 field notes. Sherman Day (1854) also noted a "point of timber" close to his survey line in this area. (Blake 1885, courtesy of the Gilroy Museum)

stands dominated by valley oaks. East of Gilroy, Sherman Day (1854) reported "timber is mainly of white oak," while directly on the other side of the valley he found "white oak, with a few live oaks." Close to Morgan Hill, he was "amid a grove of white oaks and live oaks." Despite the low composition percentage, there is evidence that live oaks were the more dominant feature in some locations. In one example, Sherman Day remarks on his entrance into "a grove of tall old live oaks" near the confluence of Tar Creek and the Pajaro River. Such variation in species composition of the oak woodlands and savannas is probably most distinct in and around Morgan Hill, where live oak canopies dominated the landscape immediately around the present-day city. Looking north toward Morgan

Hill from Uvas-Carnadero Creek, travelers saw "beautiful groves of live oak trees" and "many live oaks, some of them very large and beautiful" (Linkins 1874, Manly 1894). Some of these remain today (fig. 6.9). However, further east, valley oaks (such as those illustrated in the Dunne Ranch photograph; fig. see 6.6B) are the dominant oak species. This area was crossed by the GLO surveys, not the west side of the valley at Morgan Hill, which could explain why no live oaks were recorded between Morgan Hill and Gilroy. Other tree species, such as sycamores and willows, were recorded near creeks or rivers.

In south Santa Clara Valley, 84% of the oaks recorded to species level by GLO surveyors were valley oaks.

Associations with soils

The soils analysis provides the basis for our mapped habitat units for which GLO data can inform density estimates. We found that several soil types and textures were significant factors explaining the distribution of the 1,976 probable valley oaks digitized from the 1939 aerial photography. To check the relevance of these findings to historical distribution, we confirmed that these correlations also largely reflect the presence and absence patterns of GLO bearing tree data and other sources. We found oak presence significantly correlated (probability >90%) with Pleasanton loam (0-2% slopes), Pleasanton gravelly loam (0-2 and 2-9% slopes), San Ysidro loam (0-2% slopes), and Arbuckle gravelly loam (0-2% slopes). Largely found in association with each other, these soils are located on alluvial fans and described as well

Table 6.4. Species composition of all GLO trees within the study area. The total differs from density calculation totals because some trees did not have distances recorded and this table includes line trees (those trees with no distance because they fall on the survey line).

Species	# of trees	% of total
Valley Oak	118	65%
Black Oak	17	9%
Live Oak	6	3%
Oak (unspecified)	10	5%
Sycamore	14	8%
Willow	8	4%
Alder	1	1%
Undefined	8	4%
Total	182	

Figure 6.9. Existing heritage oak trees in South Valley are mostly valley oaks, but large live oaks are also relatively common in Morgan Hill, reflecting historical vegetation patterns. This tree was photographed in the winter, when the deciduous valley oaks were leafless.

Table 6.5. Soil type association with density, using 1939 oaks.

Name	Area (ha)	Percent of total area	Observed oaks (1939)	Expected oaks	Percent of total oaks (1939)	Oaks/ha	α = 0.1
ARBUCKLE GRAVELLY LOAM, 0 TO 2 PERCENT SLOPES	1515	7.0%	153	99	10.8%	0.10	+
CAMPBELL SILTY CLAY LOAM	536	2.5%	11	35	0.8%	0.02	-
CAMPBELL SILTY CLAY, MUCK SUBSTRATUM	951	4.4%	29	62	2.0%	0.03	-
CLEAR LAKE CLAY	425	2.0%	6	28	0.4%	0.01	-
CLEAR LAKE CLAY, DRAINED	591	2.7%	15	39	1.1%	0.03	-
CLEAR LAKE CLAY, SALINE	598	2.8%	3	39	0.2%	0.01	-
CROPLEY CLAY, 0 TO 2 PERCENT SLOPES	715	3.3%	21	47	1.5%	0.03	-
CROPLEY CLAY, 2 TO 9 PERCENT SLOPES	329	1.5%	23	22	1.6%	0.07	
HILLGATE SILT LOAM, 2 TO 9 PERCENT SLOPES	814	3.7%	76	53	5.3%	0.09	
HILLGATE SILT LOAM, 9 TO 15 PERCENT SLOPES, ERODED	275	1.3%	29	18	2.0%	0.11	
KEEFERS CLAY LOAM, 0 TO 2 PERCENT SLOPES	266	1.2%	27	17	1.9%	0.10	
KEEFERS CLAY LOAM, 2 TO 9 PERCENT SLOPES, ERODED	754	3.5%	69	49	4.9%	0.09	
LOS ROBLES CLAY LOAM, 0 TO 2 PERCENT SLOPES	382	1.8%	18	25	1.3%	0.05	
PACHECO CLAY LOAM	651	3.0%	20	43	1.4%	0.03	-
PACHECO FINE SANDY LOAM	794	3.7%	27	52	1.9%	0.03	-
PACHECO SILT LOAM, DRAINED	352	1.6%	15	23	1.1%	0.04	
PLEASANTON GRAVELLY LOAM, 0 TO 2 PERCENT SLOPES	665	3.1%	129	44	9.1%	0.19	+
PLEASANTON GRAVELLY LOAM, 2 TO 9 PERCENT SLOPES	505	2.3%	157	33	11.0%	0.31	+
PLEASANTON LOAM, 0 TO 2 PERCENT SLOPES	1707	7.9%	166	112	11.7%	0.10	+
PLEASANTON LOAM, 2 TO 9 PERCENT SLOPES	267	1.2%	27	17	1.9%	0.10	
RINCON CLAY LOAM, 2 TO 9 PERCENT SLOPES, ERODED	269	1.2%	14	18	1.0%	0.05	
RIVERWASH	596	2.7%	28	39	2.0%	0.05	
SAN YSIDRO LOAM, 0 TO 2 PERCENT SLOPES	1228	5.7%	126	80	8.9%	0.10	+
SAN YSIDRO LOAM, ACID VARIANT, 0 TO 2 PERCENT SLOPES	353	1.6%	32	23	2.3%	0.09	
SORRENTO SILT LOAM, 0 TO 2 PERCENT SLOPES	758	3.5%	39	50	2.7%	0.05	
WILLOWS CLAY	2379	11.0%	9	156	0.6%	0.00	-
Willows soils, eroded	387	1.8%	0	25	0.0%	0.00	-
YOLO LOAM, 0 TO 2 PERCENT SLOPES	1082	5.0%	78	71	5.5%	0.07	
YOLO SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	423	1.9%	38	28	2.7%	0.09	
ZAMORA CLAY LOAM, 0 TO 2 PERCENT SLOPES	846	3.9%	16	55	1.1%	0.02	-
ZAMORA LOAM, 0 TO 2 PERCENT SLOPES	311	1.4%	21	20	1.5%	0.07	

drained soils with a "deep rooting depth" (USDA [1972] 2007). GLO surveyor Howe (1851) also noted the "gravelly" texture of these alluvial fan soils in the Morgan Hill area. In his study of historic oak distribution in north Santa Clara County, Brown (2005) found that Pleasanton soils, as well as Yolo, Garretson, and Zamora soils were most likely to support oak woodland.

Soils negatively correlated with oaks include Pacheco silt, sandy, and clay loams, Campbell silty clay loams and silty clay with muck substratum, Cropley clay (0-2% slopes), Clear Lake clay, Zamora clay loam, and Willows clay (table 6.5). As might be expected, our analysis of soil textures identified fine-loamy, loamy, and loamy-skeletal textures as positively correlated with valley oak presence, while fine, fine-silty, sandy, landslide, riverwash, and water categories were significantly negatively correlated with valley oaks (table 6.6). Results from the soil texture analysis showed a much larger proportion of the study area (virtually all) falling within either positively or negatively correlated soils. While less selective, we included the soil texture analysis for its more general description and more universal use (figs. 6.10 and 6.11).

Significantly negatively correlated soil types contained only 23% of the expected number of oaks ("expected oaks" based on the number of oaks in the soil type if the 1,976 "probable" oaks are distributed evenly across the study area). Significantly negatively correlated soil textures were less useful predictors of oak absence, containing 58% of the expected oaks. With 11% of the 1939 oaks located in significantly negatively correlated soil types and 33% located in significantly negatively correlated soil textures, it may appear that these are poor indicators of oak distribution. However, these soils both represent stand densities of <0.05 trees per hectare (0.02 trees/ac), or less than 0.5% canopy cover, which

Table 6.6. Soil texture association with oaks density, using 1939 oaks.

Particle Size (texture)	Area (ha)	Percent of total area	Observed oaks	Expected oaks	Percent of total oaks	Oaks/ha	Significant α=0.1
Clayey	193	0.7%	28	15	1.4%	0.145	
Clayey-skeletal	1020	3.8%	96	77	4.8%	0.094	
Fine	9165	34.6%	396	691	19.8%	0.043	-
Fine-silty	4639	17.5%	239	350	12.0%	0.052	-
Fine-loamy	9208	34.7%	1020	695	51.0%	0.111	+
Loamy	116	0.4%	46	9	2.3%	0.395	+
Loamy-skeletal	250	0.9%	44	19	2.2%	0.176	+
Coarse-loamy	841	3.2%	81	63	4.1%	0.096	
Sandy	181	0.7%	1	14	0.1%	0.006	-
Riverwash and water	785	3.0%	32	59	1.6%	0.041	-
not used	114	0.4%	17	9	0.9%	0.149	

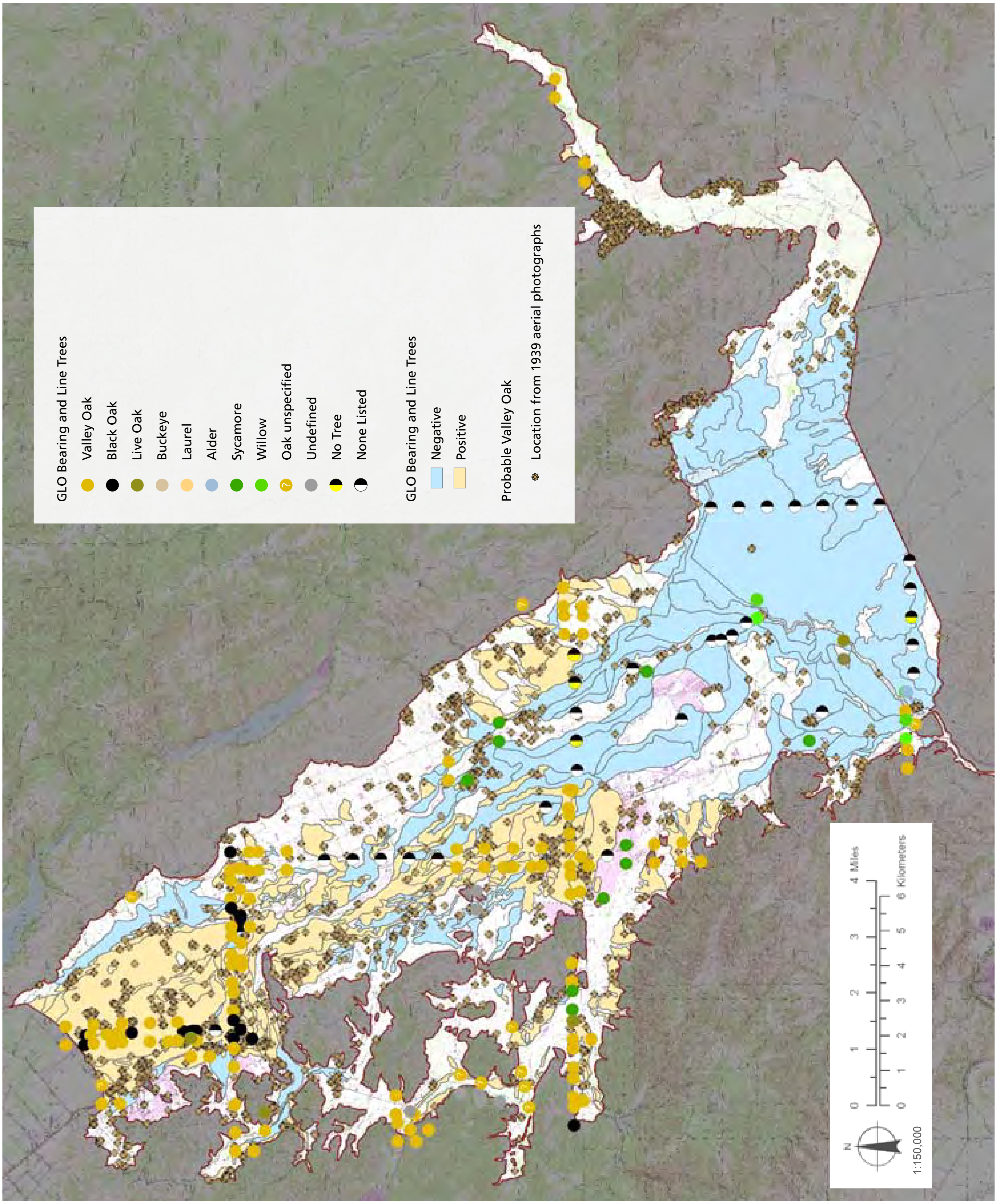


Figure 6.10. Soil types that are positively (yellow) and negatively (blue) associated with oak presence (from 1939 aerial photography) with a significance level <0.1. Areas were left blank for soil types insignificantly correlated with oaks.

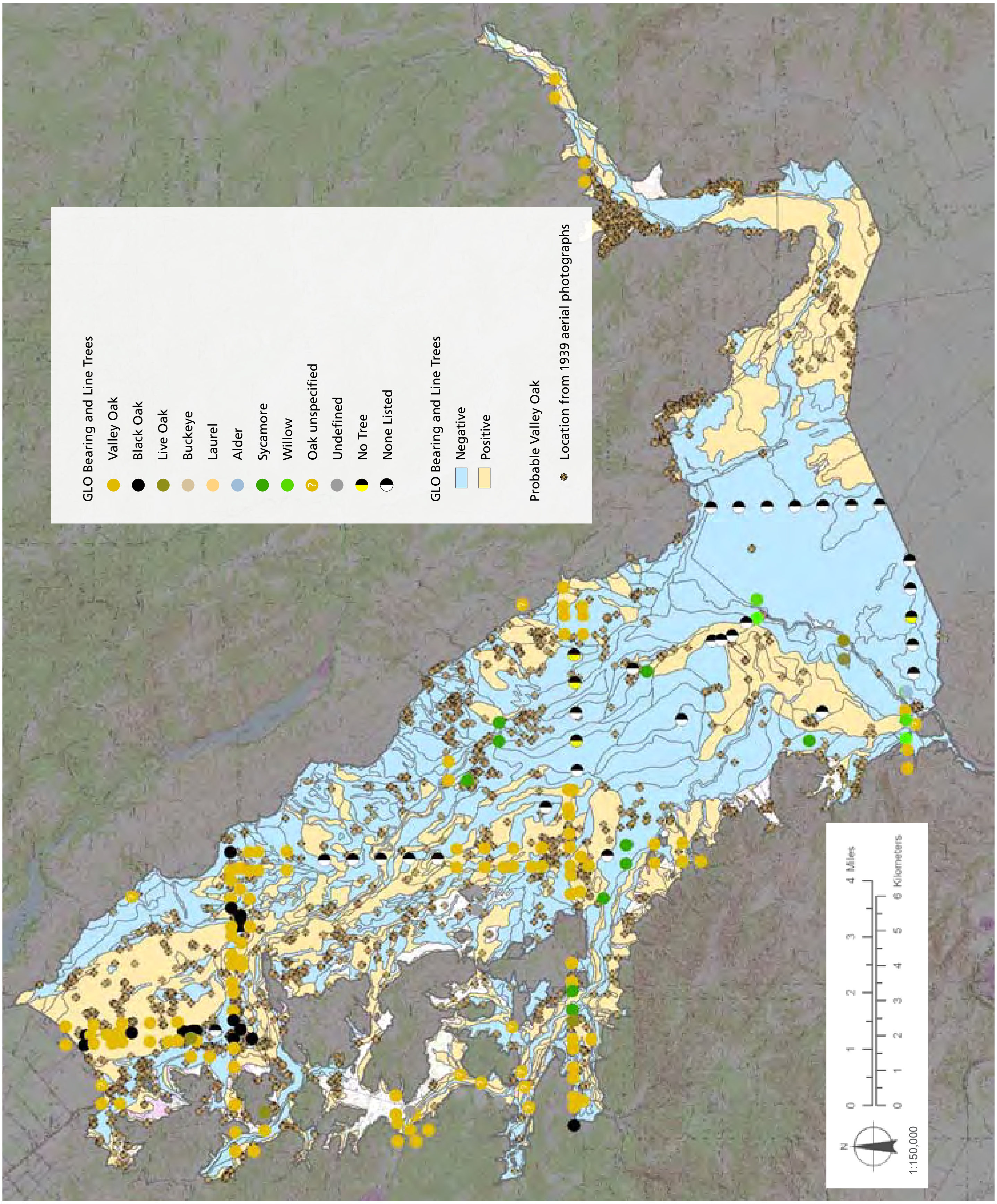


Figure 6.11. Soil textures (based on the soil survey particle size) that are positively (yellow) and negatively (blue) associated with oak presence (from 1939 aerial photography) with a significance level <0.1. Areas were left blank for soil types insignificantly correlated with oaks.

corresponds with maximum possible densities indicated by GLO data points that contain no bearing tree information. By comparison, positively correlated soils are associated with 1939 oak densities of >0.1 trees per hectare (0.04 trees/ac). These levels clearly do not reflect the high historical densities suggested by the GLO data, but the locations of high density in the GLO data match those soils highly correlated with the 1939 "probable" valley oaks.

Narrative sources also illustrate the lack of trees in the Bolsa region, the most distinctive body of negatively correlated soils. Brewer, riding across the Bolsa in 1861, described the treeless region:

> First a ride of eighteen miles across the dead-level plain, tedious and monotonous...To one who has never tried riding on a level plain, no description is adequate to cause a full realization of its tediousness...but at last a belt of scattered oaks is entered. Then we strike up a canyon, on the Pacheco Pass... (Brewer [1930]1974)

Similarly, Broek (1932) described this area as a "treeless plain," affirming the stark differences in tree density found in other parts of the valley.

When comparing these negatively correlated soils to historical soils identified for their wet characteristics with poor growing conditions, such as alkaline, adobe, poorly drained, and seasonally flooded (Grossinger et al. 2007a), the negatively correlated soils largely overlap. Alkaline soils represent 15% of the study area (located in the Bolsa region) but contain only 1% of the total oaks (or only 7% of the expected number of oaks had all oaks been evenly distributed across the study area). These negatively correlated areas correspond closely with the "no tree" points recorded by GLO surveyors. This is not to suggest that oaks cannot grow in these areas; finer-scale micro-topography such as ridges built up from abandoned streams can provide favorable, albeit limited, locations for oak establishment (Cooper 1926).

Change over time

Based on our mapped habitat polygons (see habitat map, inside front cover) and representative average densities from the GLO dataset for points within each habitat type, we estimate that close to 60,000 oaks existed within south Santa Clara Valley during the early settlement period. Using the habitat classification ranges for percent canopy cover, estimates range from 35,000 to 110,000 historic oaks. This is striking when compared to the 1,976 "probable" valley oaks identified in the 1939 aerial photography, and the rough estimate of about 1,000 persisting in 2005 (fig. 6.12).

Based on our approximate density estimates, the average woodland density declined from 13 trees/ha to 0.2 trees/ha (5.3 trees/ac-0.1 trees/ac), while savanna density decreased from 2.9 to 0.1 trees/ha (1.2 trees/ac-0.04 trees/ac). The density decrease between the 1939 digitized trees and those currently standing (as of 2005) is fairly uniform, decreasing by roughly half for both woodland and savanna areas. This means that approximately 97% of the mid-1800s oaks were lost by 1939. Since then, an additional 50% have been lost. These estimates are likely best considered as minimum or low estimates given that the 1939 and 2005 oak populations were based on digitized trees from aerial photography, a method which tends to underestimate density.

For comparison, studies in southern California found losses of approximately 20% between the late 1930s to early 1940s and the late 1980s and 1990s (Sork et al. 2002, Mahall et al. 2005). These studies occurred in areas less impacted by agriculture and urban growth. This difference and the extensive conversion of the south Santa Clara Valley floor to orchards and row crops suggests that the reported losses can largely be attributed to land conversion rather than the lack of regeneration.

The corresponding estimates of historical area are 5700 ha (14,000 ac) of oak savanna and 3,300 ha (8,200 ac) of oak

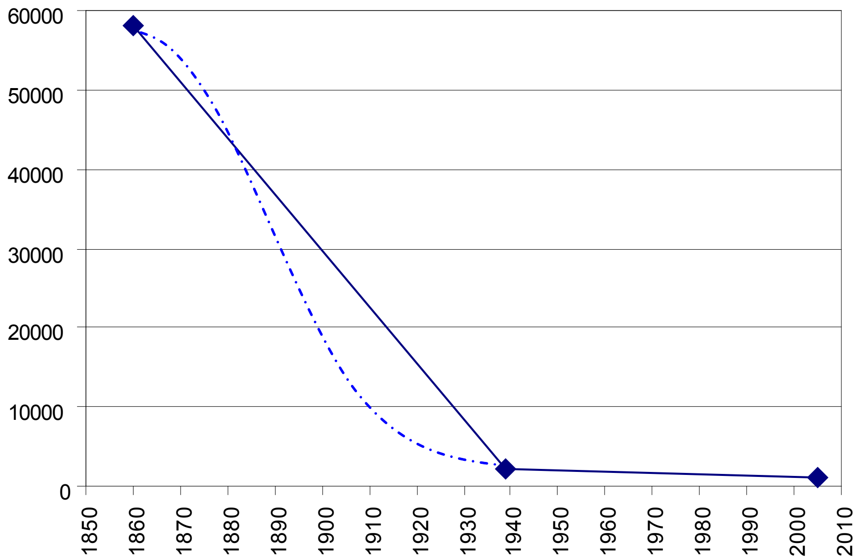


Figure 6.12. Decline in oaks over time based on estimates reflecting the early settlement period, the period after agricultural intensification, and contemporary numbers. Estimated trend based on land use history in dashed blue line.

woodland. Together these habitats represent about 34% of the study area. Recent mapping indicates 164 ha (400 ac) of equivalent habitat ("mixed oak woodland and forest" and "valley oak woodland;" Jones and Stokes 2006) in the Santa Clara County portion of the study, which covers 80% of the study area. Assuming a similar proportion of savanna/woodland for the San Benito County portion of the study area (which is undoubtedly an overestimate given the dominance of wetland soils), the decline is 98%.

Open grasslands have also declined, although not quite as precipitously. We estimate 8,500 ha (21,000 ac) historically, while recent mapping indicates 1,188 ha (2,900 ac) in the Santa Clara County portion of the study area.

DISCUSSION

Historical data intercalibration

Determining the historical extent of valley oak savannas and woodlands involved inter-calibration between quantitative data (GLO nearest neighbor bearing tree distance), historical cartographic depiction, and descriptive terminology. These different styles of data combine to reveal consistent landscape patterns. We found that surveyors and cartographers from a wide range of backgrounds depicted woodland and savanna in similar ways. In general, neither Spanish nor American cartographers show savanna, but each consistently shows groves or woodlands. These visual depictions of groves consistently correlated with spatially explicit GLO surveys that use the terms "grove" or "woodland" as well as the higher densities indicated from bearing tree distances (fig. 6.13). It appears that these dense woodland features were distinct enough to be represented consistently in a range of media. Similarly, we found that the term "scattered trees" was used consistently by surveyors to refer to a more open savanna pattern, based on corresponding bearing tree data. These areas were rarely depicted on early maps. This understanding helped to classify areas into woodland, savanna or grassland, while also refining habitat extents based on soil correlations with the 1939 "probable" valley oaks.

Figure 6.13. GLO surveyor Sherman Day intersected the feature drawn by county surveyor Lewis (1850a) on the right side of this map. Day (1854) noted "Enter timber — white oaks," corresponding with Lewis' representation of a densely wooded area. The distinctive "abra," or opening, is labeled at (a). (Lewis 1850a, courtesy of the Office of the Santa Clara County Surveyor)

Soils associations

Although we used the digitized 1939 oaks rather than oaks from earlier sources to determine soils strongly correlated with the presence or absence of oaks, we expect to only lose significance using this later source and thus underestimate historical extents of woodlands and savannas. It could be that some soils with historically high tree densities were completely cleared of oaks by 1939. However, losses appear relatively evenly distributed across the valley such that the relict oaks of 1939, largely found along roads and at homesites, seem sufficient for determining positively and negatively correlated soils. We would expect losses to occur at a more local level (at the agricultural field level), and thus not affect trends in relative densities across the valley. The valley floor in 1939 was mostly covered in agriculture, and yet these correlations are able to distinguish between different areas within the cultivated region. Our analysis reveals that certain soils could be indicators for potential areas of restoration, or (in the case of the alkali soil type) areas where restoration efforts might have little potential to succeed.

Significantly correlated soil types can suggest potential areas to reintroduce – or not reintroduce – oak populations

Stand densities

Our estimates of historical stand densities appear to fall within the range of those reported in other studies, although no quantified estimates of density were found prior to the 1930s. Sork et al. (2002) reported an average 1944 density of 1.48 valley oaks per hectare (0.6 oaks/ac) located on the Sedgwick Reserve in Santa Ynez, California. Davis et al. (2000) found a valley oak density of 1.7 trees/ha (0.7 trees/ac; using 22,647 canopy-sized valley oaks on 44,000 ha (108,700 ac), derived from polygons that contained valley oaks). Also on Sedgwick Reserve, a 2005 report found overall 1943 oak densities of 13.5 trees/ha (5.5 trees/ac) based on 20 oak woodland stands identified in 1943 aerial photography (Mahall et al. 2005).

Oak patterns and land use history

Findings suggesting that the majority of oaks were lost prior to World War II is supported by the history of land use in the valley. Local history also indicates that the GLO surveys, upon which we base our estimates of historical oak densities, occurred at the cusp of rapid settlement and cultivation in the valleys and thus largely reflect pre-modification conditions. It appears that large scale removal of trees had not yet occurred by the 1850s and 1860s, even though Spanish colonization in the region began in the late 1700s. Most of the South Valley land passed through by GLO surveyors was described as open plains with only occasional cultivated fields. Land uses into the late 1860s focused on grazing and the production of hay and grain, which did not directly conflict with the presence of oaks (see fig. 3.1). Cattle ranchers considered oaks a benefit to rangeland, since they provided shade for stock (Jepson 1910, Bartlett 1928), and 19th-century photographs and lithographs frequently show cows under oak trees (e.g., Thompson and West 1876, Shortridge [1896]1986). Accounts that "everywhere scattered in the fields and rising above the surrounding fruit trees are large live oaks with widespreading crowns" (Broek 1932) or that trees were "not so close together as to render it necessary to cut away to prepare the land for cultivation" (1850s, in Bartlett 1965) suggested that oaks and agriculture were not mutually exclusive. Descriptions and photographs indicate that oaks were usually left intact within 19th-century hay and grain fields, so that by the 1890s the remaining grain farms in the county were noted for their preservation of "the grand old oaks in all their original beauty" (Shortridge [1896]1986).

Equally important, valley oak wood is too soft for building purposes (Jepson 1910), and did not receive the same pressures as the redwoods in the nearby Santa Cruz Mountains, which were the preferred source of lumber during the early settlement period. While some trees were undoubtedly removed in the immediate vicinity of settlements or used for firewood and even occasionally as fence posts during this early transition period (Jepson 1910, Brown 2002), these factors did not drive significant clearing until the large-scale planting of orchards. Consequently, we expect our estimate of historical oak coverage is an accurate approximation of conditions at the time of European contact.

> Oak trees did not directly conflict with Mexican-era and early American agricultural practices. Oak mortality was greatest during the late 19th century, with gradual attrition since that time.

It should also be considered whether baseline levels assumed from the 1850 picture were affected by the rapid decline in the fire regime practiced by indigenous land management (Barbour et al. 2007). However, intensive ranching almost immediately followed European contact and likely would have overwhelmed any effects of a reduced fire regime toward producing denser stands (Keeler-Wolf pers. comm.). If anything, it is likely that the valley vegetation was more restricted following European settlement. The oak woodlands and savannas are distinctive and stable features in the earliest maps and accounts, suggesting that these stands were well established before Spanish contact. Also, research shows that oak pollen remained steady in the periods leading up to European contact and was followed by a sharp decrease in levels in the early settlement period (Barbour et al. 2007). In South Valley, subregional variation shown in the historical sources is reflective of persistent controls such as soils, topography, and groundwater.

After surviving the first century of Euro-American presence relatively intact, oak trees found themselves in direct conflict with fruit and nut orchards in the last decades of the 19th century. Oaks competed for sunlight and space within the dense tree spacing of orchards, so settlers no longer desired the large spreading canopies of the oaks, at least not in their cultivated fields. For example, prunes were typically spaced 20 ft apart, at densities of 108 trees/ha (44 trees/ac; Shortridge [1896]1986), making a large oak a significant impediment. It was during these decades – 1870s-1910s – that widespread clearing took place as grain fields and pastureland were converted to orchards. The value of the trees for firewood was an additional but secondary benefit to large-scale clearing:

> The land is being cleared as opportunity offers. Stove wood commands such a good price, however, that the work is done at a profit. (Shortridge [1896]1986)

> The wood secured in clearing the land was quite an object, as live oak stove wood commanded $6.50 per cord, on the ground, and white oak $5.50. (Shortridge [1896]1986)

The conversion to orchards resulted in a dramatic loss of valley oaks during this period. By the beginning of the 20th century, in most of the former oak lands only scattered trees remained along orchard margins or as remnant stands within homesteads or small pastures (fig. 6.14). Fortunately, several large ranches, such as the Dunne Ranch in the Morgan Hill-San Martin area, were subdivided relatively late (Harrison ca. 1888, Sharma 2005), allowing them to be documented in landscape photography of the 1890s (see fig. 6.6). Given this rapid transition, it is not surprising that our estimate of relict valley oaks in 1939 is just 3% of our estimate for oaks present in the 1850s.

During the post-World War II era, the expansion of urban and suburban areas has further impacted oaks, although at an overall slower rate. These added pressures, plus the natural mortality of oaks, appear to have decreased the 1939 abundance by approximately 50%. With low recruitment rates of valley oaks and intensive local land use, few young oaks have grown up to replace those that have died. It also remains to be seen whether young oaks will be able to survive in many of highly urbanized or irrigated regions where relict oaks exist today. Today's remnant mature stands are largely confined to the valley margins, areas less desirable for agriculture and development.

Fine scale variation in spatial pattern

Our mapping attempts to capture the larger-scale patterns and likely distribution of oaks. Evidence of density variations and spacing patterns within savannas and woodlands created a structural complexity largely lost in the contemporary landscape that should be considered in restoration planning. Density distribution is scale dependent, such that small groupings or patches of denser "groves" fit within a broader savanna setting (Grossinger and Beller in press). Only the larger and better documented of these are likely shown in our map. This finer scale spatial distribution of trees is a potentially important factor when considering an overall density measurement. Factors contributing to local variations in density may include finer-scale physical conditions (e.g., alluvial ridges from historic channels, clay soil intrusions, groundwater levels), which we were not able to recognize in the mapping process. While the local variations in density are difficult to distinguish spatially from the historical record, illustrative quotes and historical images indicate that densities varied at many spatial scales. It is therefore important to consider local scale

Figure 6.14. In the 1935 image (A), orchards cover most of the formerly wooded Morgan Hill area. Remnant isolated trees are mostly associated with farm homesteads. In the far right background, and in the picture below, groups of oaks can be seen in remnant pasturelands. (A: Unknown 1935, courtesy of the Santa Clara Valley Water District; B: Unknown ca. 1923, courtesy of the Gilroy Museum)

oak distribution patterns as well as general landscape density variation in any restoration plan.

Current remnant distribution

Despite their relatively sparse coverage in terms of percent canopy cover, oaks have a comparatively dominating presence in the landscape. While their numbers have declined dramatically since the 1860s, the majestic oaks of the valley have been much appreciated through the history of south Santa Clara Valley and remain well-recognized today. Remnant trees of the former savannas and woodlands are carefully preserved in yards, parks, housing developments, and even warehouse districts (fig. 6.15). A few larger stands can still be found in agricultural fields (see fig. 6.17) and on parcels of undeveloped land on the valley margins.

Social and ecological value of remnant oaks

The oaks represent a significant part of the cultural and natural heritage of the region. Some modern land uses, including residential housing, pose less direct conflict with oaks than do orchards. While oak trees compete with orchard trees for sunlight, oaks can function as shade trees and aesthetic features within urban and residential settings. Valley oaks and live oaks are recognized as suitable street trees in a number of California cities (e.g., Los Angeles, Davis, Morgan Hill) and, because of their size, are particularly effective for medians, yards, and parks. The city of Morgan Hill has successfully planted live oaks in medians for a number of years because of the trees' tolerance of drought and high temperatures (Beale pers. comm.; fig. 6.16). The utility and cultural appeal of the oaks have been noted for over a century:

> [Gilroy] was formerly covered with groves of magnificent oak trees, many of which yet remain, giving to the locality a natural park like appearance... (Shortridge [1896]1986)

Ecologically, establishment of general historical oak land densities in parts of south Santa Clara Valley could have significant benefits. As trees mature, they would rapidly begin to provide habitat for a number of oak-associated species. Achieving close to historical densities may help support birds such as acorn woodpecker, which were historically common in the valley but are now rarely seen in valley floor areas lacking oaks (Rottenborn pers. comm.). Other species associated with valley oak ecosystems include white-breasted nuthatch and the oak titmouse. Benefits include available nesting and granary sites and linkages to adjacent hills and creeks, although some of these needs can be served by other tree species and/or artificial sites (Bousman 2007).

Valley oaks are also important to the Pacific pallid bat, a non-migratory species that typically occupies valley oak savanna habitat. This special status bat utilizes tree cavities and crevices created by the exfoliating bark of valley oaks and other large trees for day roosting habitat (Johnston et al. 2006). Pallid bats forage primarily on terrestrial invertebrates (e.g., Jerusalem crickets, centipedes, and darkling ground beetles) found among the fallen decaying branches under the oaks and in the surrounding grassland habitats (Johnston and Fenton 2001). Coastal pallid bat populations have continued to decline since the California Department of Fish and Game designated the species as a species of special concern in 1986 (Johnston and Stokes 2007). The restoration of valley oak lands and their ecosystem functions, along with stewardship of adjacent grassland and riparian habitats, could have significant benefits for the Pacific pallid bat by providing reliable roosts and foraging areas. As with oak-associated birds, planning for the preservation of old limbs and understory litter where possible, including leaves and fallen branches, will increase the effective habitat value.

Threats to remnant oaks

Despite general appreciation and some preservation, local oak populations continue to decline. Many trees persist as relicts of the past in agricultural fields, parking lots, or around manicured parks and homes, where natural recruitment of young trees is difficult, if not

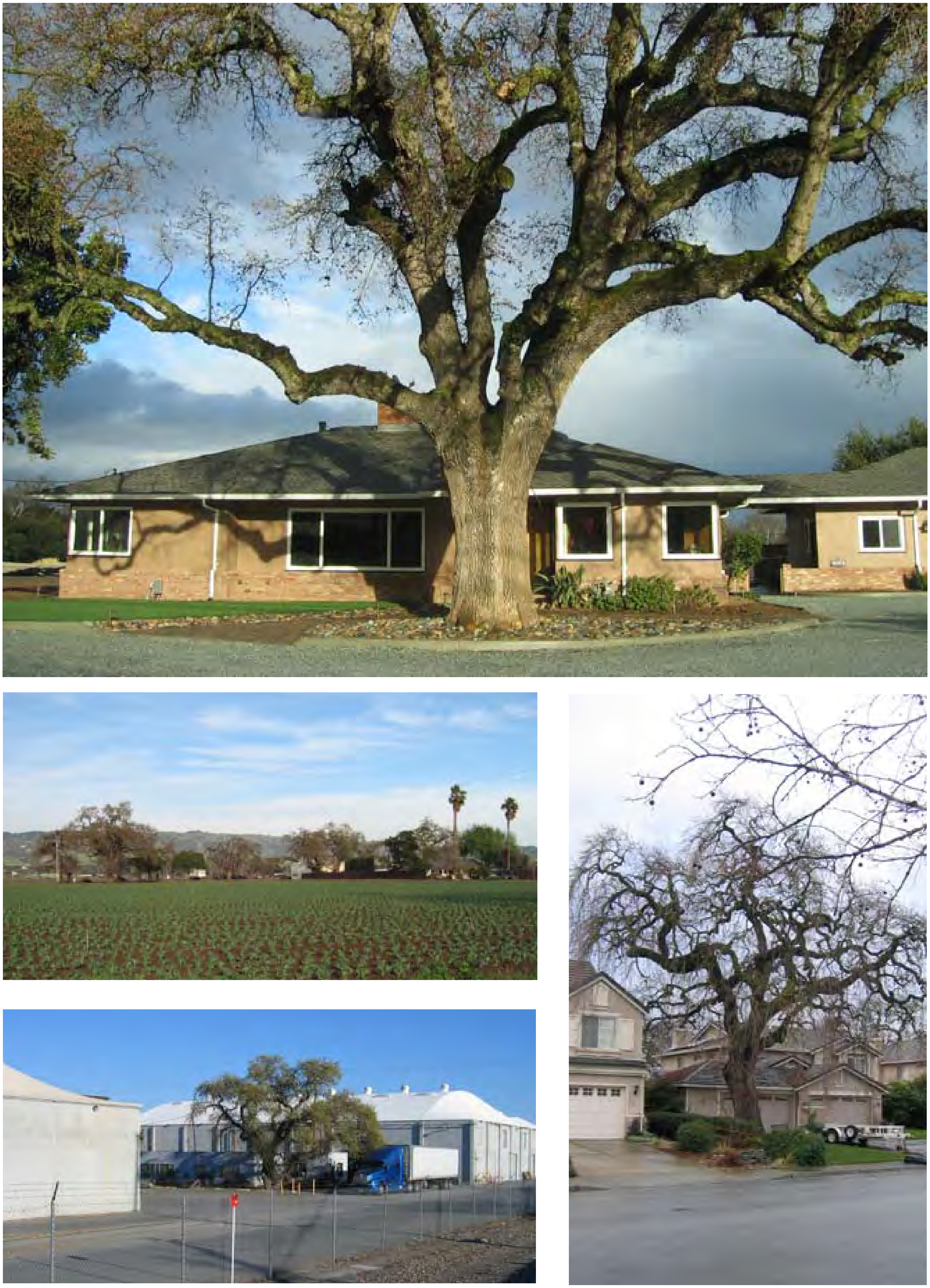


Figure 6.15. Valley oaks in the contemporary landscape.

Figure 6.16. Street medians in Morgan Hill are frequently planted with live oaks because of their ability to tolerate the harsh site conditions.

impossible. The trend towards more intensive summer irrigation in parts of the valley is likely to have negative effects on existing oak populations (fig 6.17). Development pressures also threaten existing trees. Without active stewardship to recruit new trees and conservation measures for those that exist, valley oaks are likely to disappear almost completely from the valley floor in coming decades as older trees die naturally or are removed.

Increasing oak density in the valley is important for maintaining the genetic viability of local valley oak populations. In addition to the direct loss of trees, declining genetic diversity and the possibility of reproductive isolation of the now highly scattered valley oak trees may limit successful seed production and the fitness of seedlings (Sork et al. 2002). Although relatively little is known of the regional and local genetic variation and its significance for adaptation, genetic diversity may prove to be a significant factor determining valley oak persistence into the future, and further efforts should be made to learn more. The average

Figure 6.17. This rare group of valley oak trees east of Gilroy has been preserved through a century or more of agricultural land use. However, there is no evidence of recruitment and more intensive irrigation practices may be deleterious to the continued persistence of existing trees.

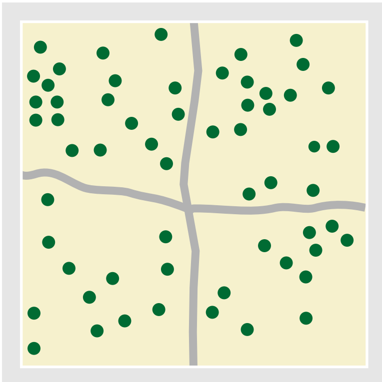
Figure 6.18. While these valley oaks in a Morgan Hill residential community have been well preserved and are fortunate to have some immediate neighbors, the lack of younger trees suggests that the future of the local valley oak population is uncertain.

spacing we observed of approximately 30 m (100 ft) from historical GLO data is consistent with healthy neighborhood sizes, given estimates of average pollen dispersal distance for the species of 65 m (210 ft; Sork et al. 2002). Reintegrating valley oaks within present-day south Santa Clara Valley could help support local populations in their resiliency to climate change and other environmental trends.

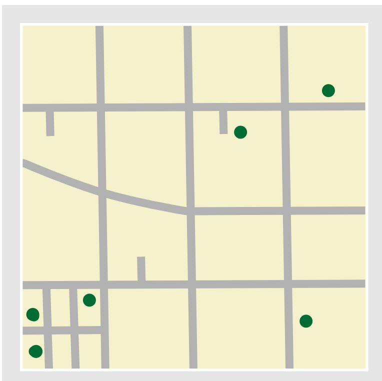
Opportunities for restoration and improved management

Despite their aesthetic and ecological significance, however, valley oaks occupy little of the actual land area. The density and distribution patterns associated with the native woodlands and savannas could be strategically re-introduced within the urban and suburban landscape, where oaks can serve as shade trees. Valley oaks are particularly effective in this function, casting a "high shade" in the summer and allowing light through in the winter months as they drop their leaves. Under suitable conditions, the trees grow rapidly, often reaching a height of 12 m (40 ft) in 25 years (Bornstein et al. 2006). Within agricultural areas, oaks can be placed along roadsides, fence lines, and occasionally within fields (fig. 6.15). Less dense savannas with canopy cover between 10% and 25% (approximately 3 to 6 trees per hectare/1.2 to 2.4 trees per acre) could be interspersed between denser woodlands or groves located in parks or areas of open land (fig. 6.18 and 6.19). Such densities could fit within many contemporary landscape patterns (Grossinger et al. 2007a). Although simply increasing tree density would not address broader goals of conservation and restoration of valley oak or mixed oak ecosystems, such efforts could provide for specific species' needs as well as help ensure oaks continued presence in the landscape. A program for reintroducing urban oak trees would involve consideration by arborists and ecologists of horticultural factors such as infrastructure constraints, appropriate watering regimes, and maintenance.

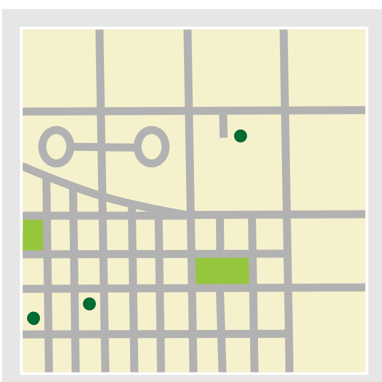
While oak patterns are greatly diminished in the present-day landscape, several significant oak groves still remain along the valley margins. These features, which have been preserved by local and private stewardship, would be worthy of long-term conservation attention as part of a regional plan to restore, not just individual trees, but also valley oak and mixed oak ecosystems. Remnant groves such as those along Highway 152 (near San Felipe Lake and along Pacheco Creek, see figs. 6.4C and 6.4D) represent the best remaining local examples of these habitat types. In contrast to oaks within an urban environment, such areas have added ecosystem benefits with the associated understory vegetation as well as other components such as riparian areas and connections to upland habitats. These features can serve as reference systems for regional restoration efforts and may also be reservoirs of local genetic diversity, with larger genetic neighborhoods and connection to upland populations. Facilitating oak seedling recruitment in these areas (e.g., through enclosures, grazing management) could aid their long-term persistence.



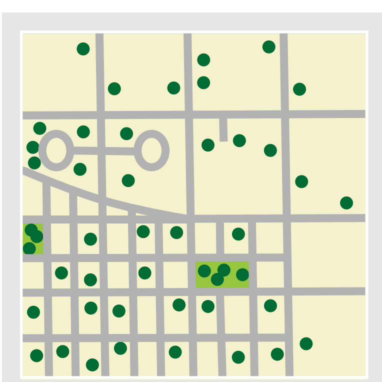
Circa 1800: Valley oaks occur in varying densities. Visitors identify dense groves, areas of "scattered" trees, and open "glades." Dirt roads go around trees and, for the most part, so do ranching and early agricultural activities.



Pre-World War II: Most of the valley floor has been cleared for orchards, but a few trees remain in pasturelands, along roadsides, and as a shade trees in town and on farms.



2008: Despite some preservation of existing trees, oak decline continues. Residential and commercial development expands into former orchards.



Conceptual restoration model: Similar densities and patterns to historical conditions could be achieved through strategic planting and stewardship along roads, in parks and yards, and other areas.

Figure 6.19. Oak savanna and woodland: conceptual model of landscape trajectory

7 LOCAL LANDSCAPE DESCRIPTIONS

Above. Diseño showing willows and marsh along Pacheco Creek and San Felipe Lake. *Below.* A Valley oaks occupies alluvial deposits, slightly above the broad, flat, low basins (historically alkali meadow). Willow groves at the clay soil margin may be seen in the background.

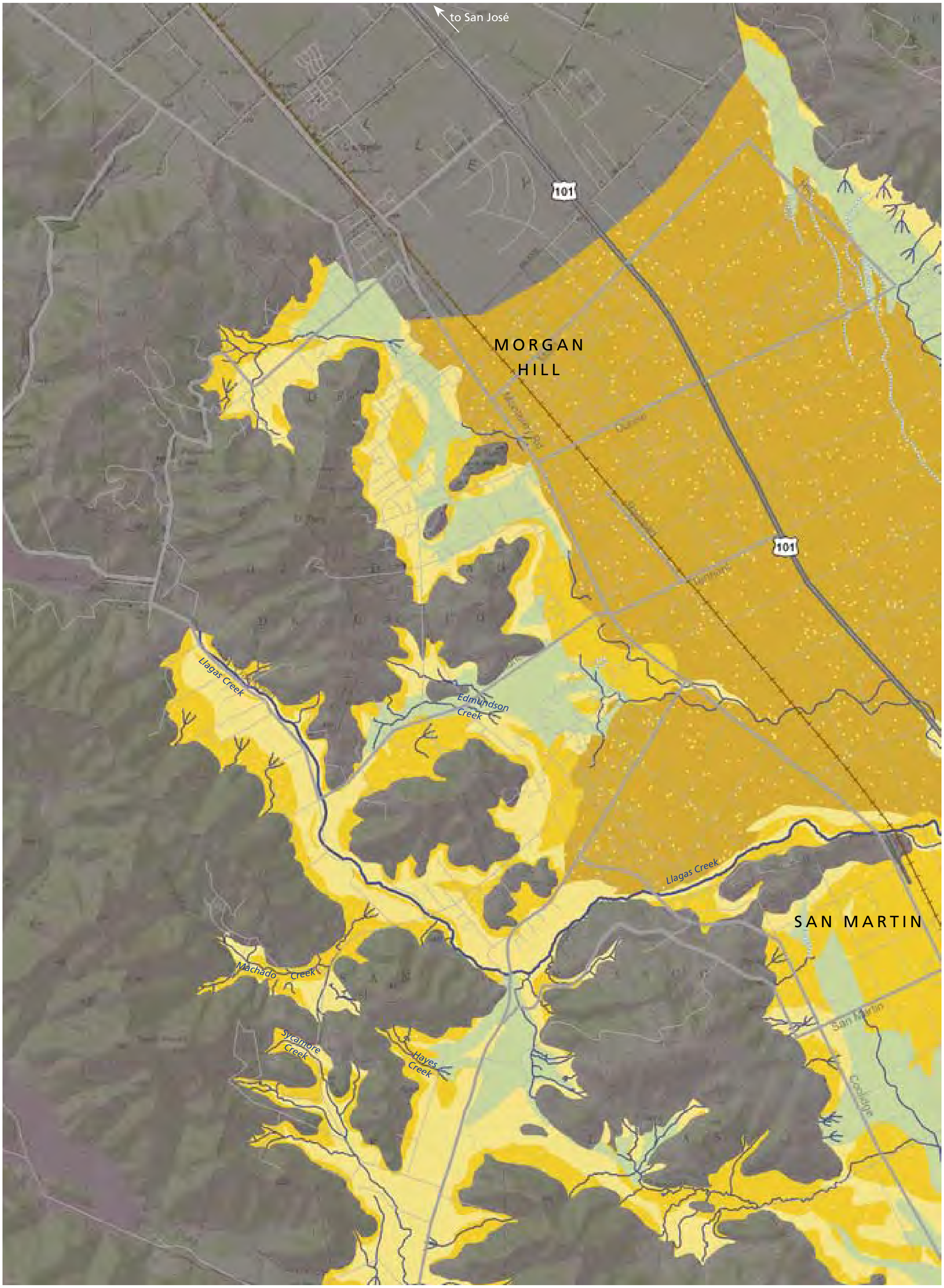
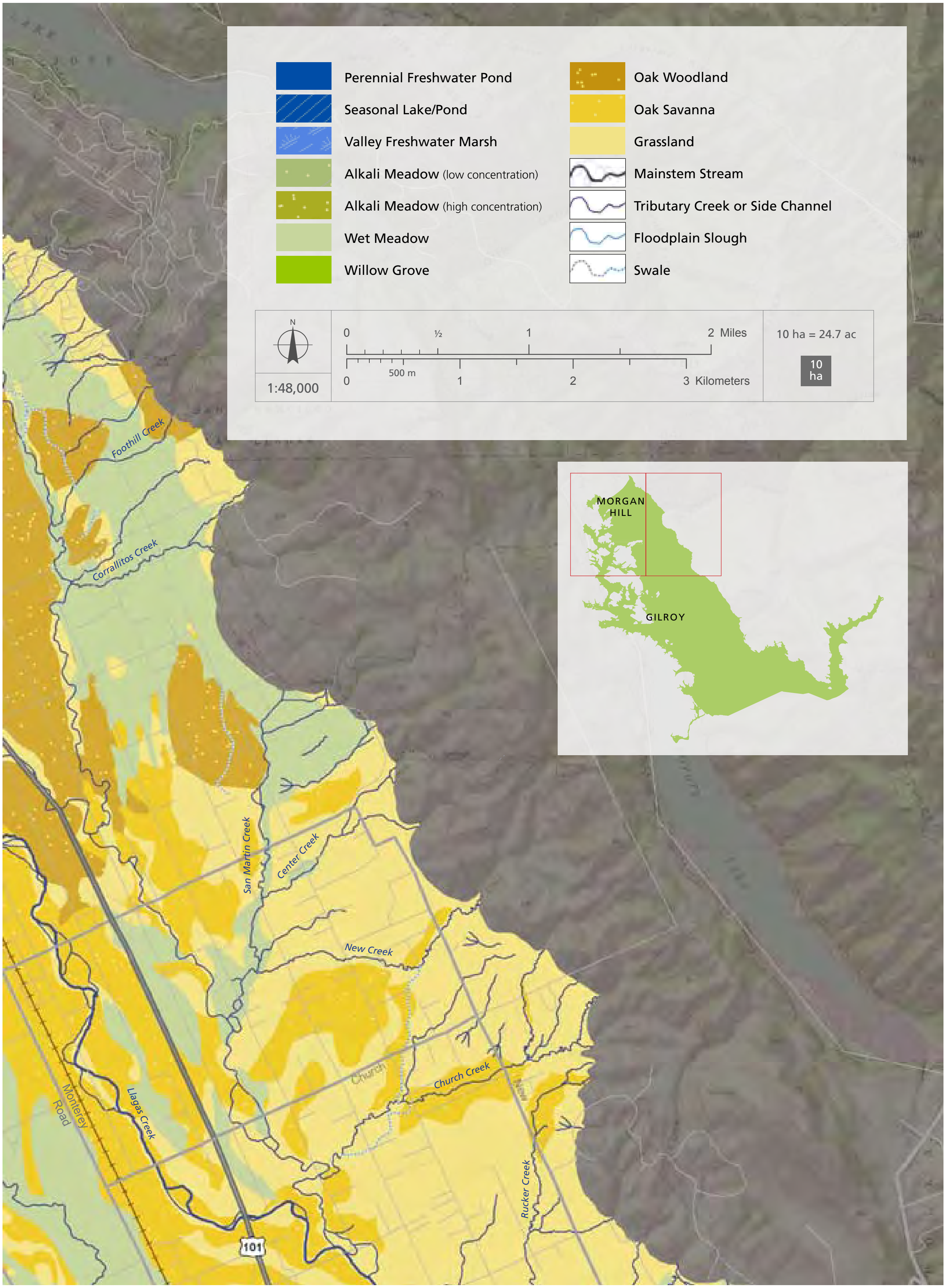


Figure 7.1. Reconstructed land cover map of south Santa Clara Valley prior to significant Euro-American modification (Morgan Hill area).


Perennial Freshwater Pond
Seasonal Lake/Pond
Valley Freshwater Marsh
Alkali Meadow (low concentration)
Alkali Meadow (high concentration)
Wet Meadow
Willow Grove
Oak Woodland
Oak Savanna
Grassland
Mainstem Stream
Tributary Creek or Side Channel
Floodplain Slough
Swale
N
1:48,000
0 ½ 1 2 Miles
0 500 m 1 2 3 Kilometers
10 ha = 24.7 ac
10 ha
MORGAN HILL
GILROY
Foothill Creek
Corrallitos Creek
San Martin Creek
Center Creek
New Creek
Church Creek
Church
Llagas Creek
Monterey Road
Rucker Creek
101

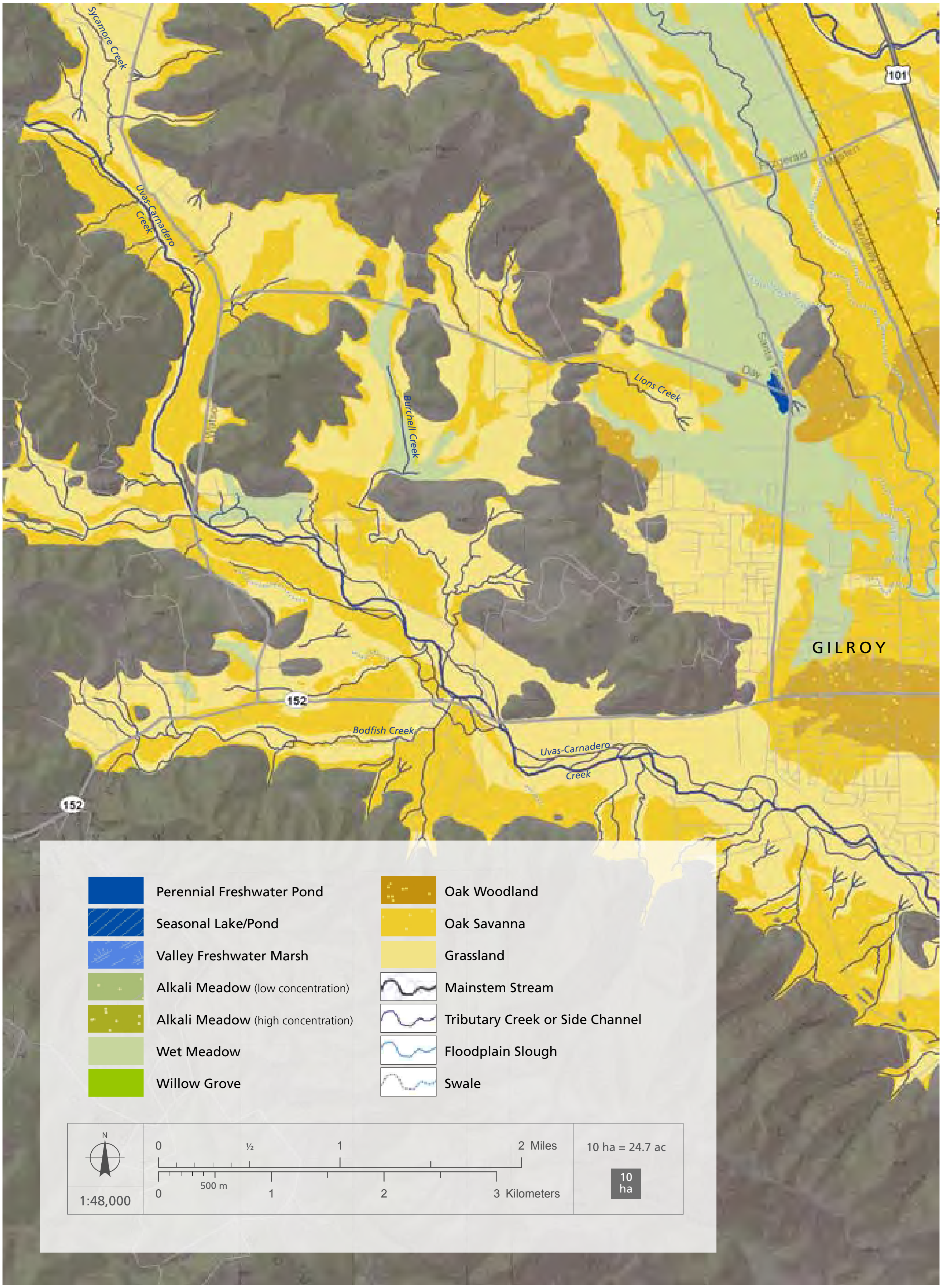
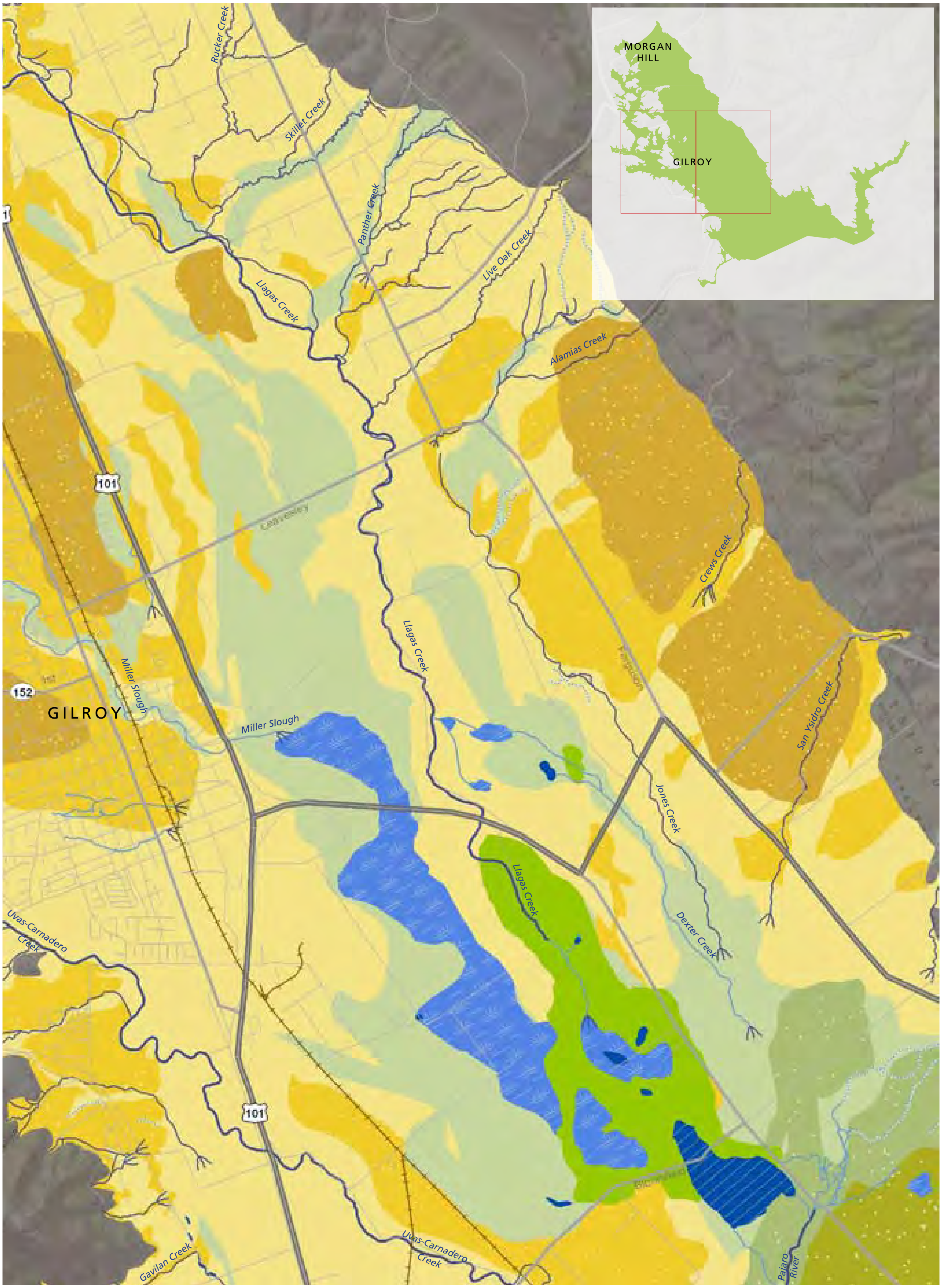


Figure 7.2. Reconstructed land cover map of south Santa Clara Valley prior to significant Euro-American modification (Gilroy area).



MORGAN HILL
GILROY
Rucker Creek
Skillet Creek
Panther Creek
Live Oak Creek
Llagas Creek
Alamias Creek
101
Leavesley
Crews Creek
Llagas Creek
Ferguson
Miller Slough
152
1st
GILROY
Miller Slough
San Ysidro Creek
Jones Creek
Llagas Creek
Dexter Creek
Uvas-Carnadero Creek
101
Gavilan Creek
Uvas-Carnadero Creek
Pajaro River

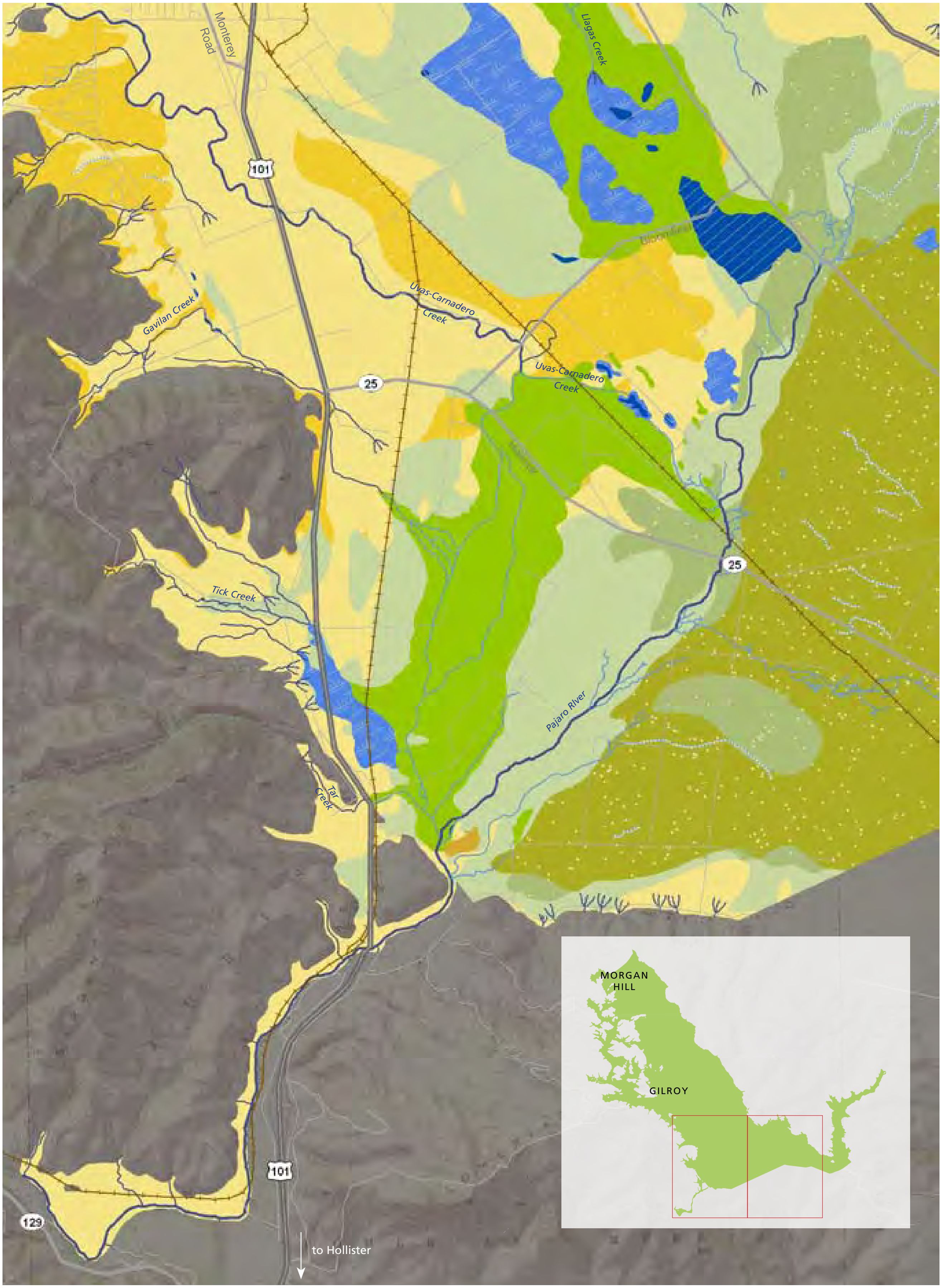
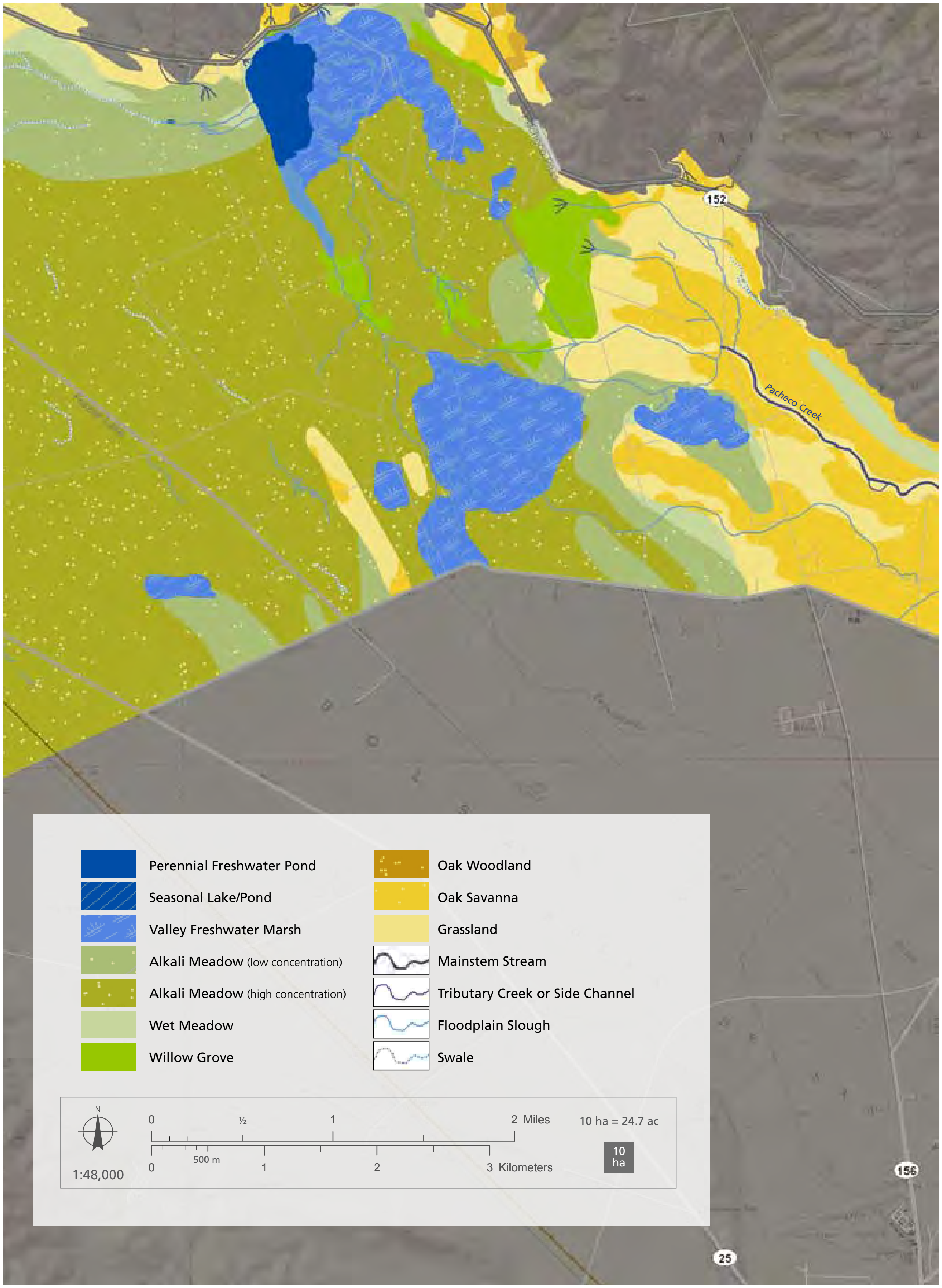


Figure 7.3. Reconstructed land cover map of south Santa Clara Valley prior to significant Euro-American modification (Soap Lake floodplain area).


152
Pacheco Creek
156
25
Perennial Freshwater Pond
Seasonal Lake/Pond
Valley Freshwater Marsh
Alkali Meadow (low concentration)
Alkali Meadow (high concentration)
Wet Meadow
Willow Grove
Oak Woodland
Oak Savanna
Grassland
Mainstem Stream
Tributary Creek or Side Channel
Floodplain Slough
Swale
N
1:48,000
0
½
1
2 Miles
0
500 m
1
2
3 Kilometers
10 ha = 24.7 ac
10 ha

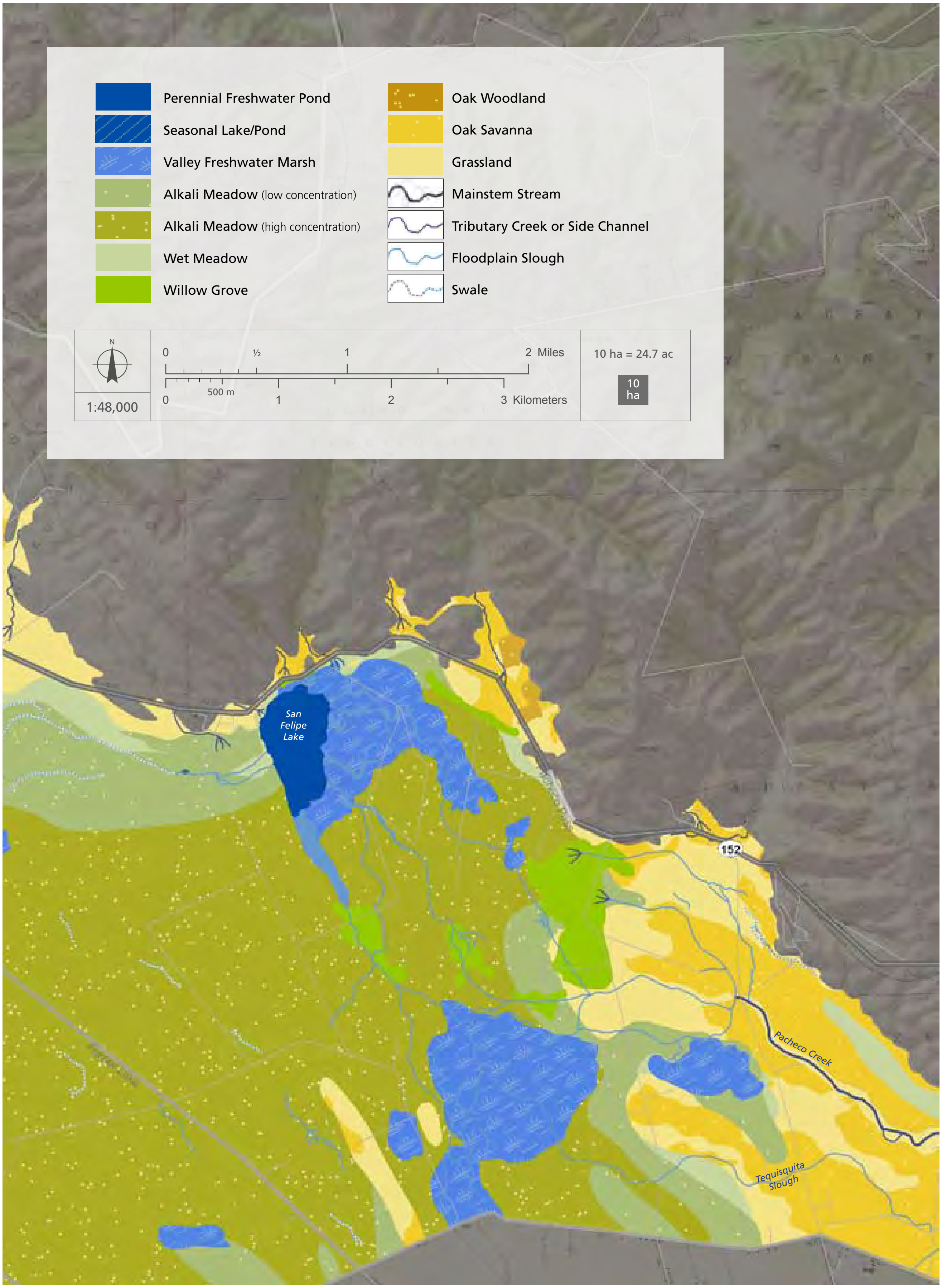
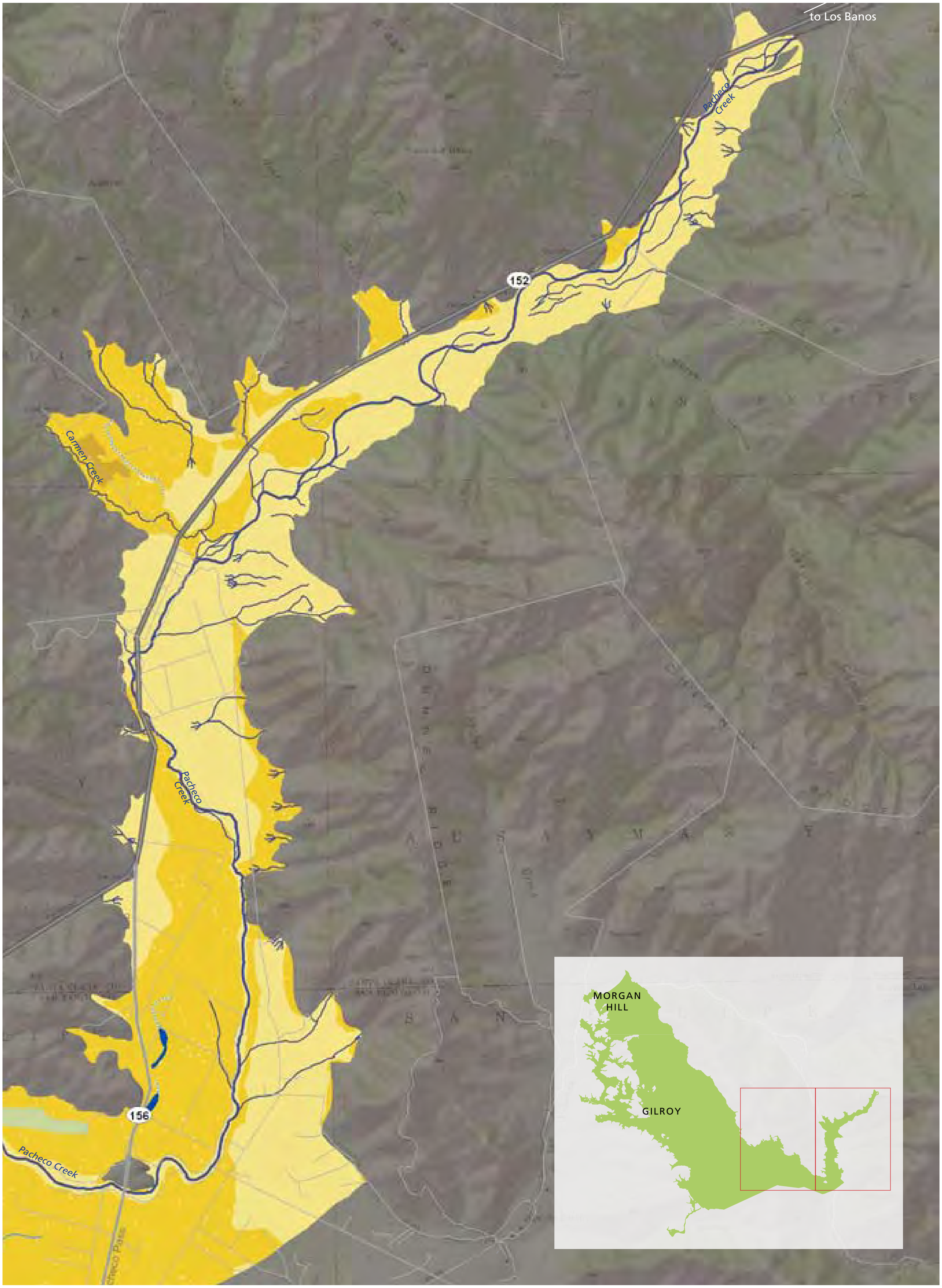


Figure 7.4. Reconstructed land cover map of south Santa Clara Valley prior to significant Euro-American modification (Pacheco Creek area).


to Los Banos
Pacheco Creek
152
Carmen Creek
Pacheco Creek
156
Pacheco Creek
MORGAN HILL
GILROY

LOCAL LANDSCAPE DESCRIPTIONS

This chapter provides additional historical evidence for and discussion of specific locales in south Santa Clara Valley. We first describe the overall landscape patterns of the South Valley, then each subregion of the study area. Level of detail varies somewhat by subregion, depending upon available information. Historical landscape patterns are shown in the full region map (inside front cover) and, at greater scale, in the preceding map series (figs. 7.1-7.4).

SOUTH SANTA CLARA VALLEY OVERVIEW

From the oak woodlands of Morgan Hill to the alkali meadows of the Bolsa, south Santa Clara Valley historically comprised a diverse array of habitats that have been integral to the ecology and culture of the region. This chapter expands upon the previous analysis to provide descriptions of what South Valley's local landscapes looked like before major Euro-American modification. We provide an overview of each stream and surrounding area, and highlight particularly notable historical features.

Many of these features were widely recognized and used (and often named) elements of the historical landscape. Perennial pools, such as the Poza de las Llagas, were valued for providing water supply to cattle, travelers, and area residents. Soap Lake was so called because ingredients for soapmaking were deposited near the lake through the seasonal evaporation of floodwaters. The oak groves near Morgan Hill provided an ideal, shady site for the town. Willow groves near Old Gilroy were a place for "camp-meetings" (Mylar [1929]1985), while residents fished, swam, picnicked, and were even baptized at the pool and island at the confluence of the Pajaro and San Benito rivers. Understanding the extent and history of these features offers us insight into not just the historical habitats of South Valley, but also the way former inhabitants of the area interacted with their landscape.

Landscape patterns shown by the historical reconstruction follow fundamental topographic, edaphic, and hydrologic controls. Varying patterns of grassland, oak savanna, and oak woodland reflect well-drained, slightly elevated alluvial fans and terraces. With lower groundwater levels relative to the soil surface, these soils stayed relatively dry in the winter, both preventing drowning and allowing for deep rooting depths (Lindsey 1974). In the summer months, the oaks' deep tap-roots could reach the water table and sustain the trees despite xeric ground surface conditions. The soil fertility and drainage characteristics of the alluvial fans that produced oak savanna and woodland also made them "splendid fruit land" (Harrison ca. 1888), and led them to largely be converted to orchards in the late 19th century.

> *"The country around Gilroy was green and wild oats were heading out and in bloom, and the wild flowers were blooming it was one of the most magnificent looking valleys that I had ever seen in California."*
>
> — JAMES EASTIN, APRIL 1850

The alluvial fans and levees created by Uvas-Carnadero, Llagas, and Pacheco creeks – and, in geologic history, Coyote Creek – dissipated into the Bolsa, spreading flood waters and fine sediments over a broad, unusually flat lowland area (Crespí described the area in 1772 as "smooth as the palm of the hand"; Crespí and Bolton 1927). Repeated evaporation of seasonal ponds left high salt concentrations in the soils of the Bolsa. These expansive, moist alkali soils were of limited agricultural value but important to the growth of Hollister's cattle industry, providing late-summer pasture when the hills were dry.

The difference between the well-drained alluvial lands and the low-lying Bolsa was striking. Broek (1932) wrote: "Nowhere in the entire Santa Clara Valley is there a more decided contrast than between the bare Bolsa plain and the densely settled, highly cultivated districts of Gilroy to the north and Hollister to the south." Except for several large, dense groves of willows, the Soap Lake floodplain supported few trees. Valley oaks, a dominant feature in other parts of the alluvial plain, were almost completely excluded by the clay soils (fig. 7.5).

As Uvas-Carnadero, Llagas, and Pacheco creeks left their steeper alluvial fans and converged into the Soap Lake floodplain, they tended to have much less well-defined channels than today, spreading (often with multiple channels) into wetland mosaics. The willow groves and marshes at the mouth of each of these three major streams were essentially deltas on the margin of the vast, seasonal Soap Lake.

Flooding could cover much of this area, forming a "great bottom-land lake" (Stimson 1944). Even into the 1940s, shallow arrays of swales and channels formed the drainage system for the lower Llagas and Carnadero area: "In the Carnadero-Llagas Creek and San Felipe Lake region, overbank flow follows low swales and depressions between the normal stream channels, merging into a large floodplain extending from the vicinity of Gilroy to San Felipe Lake and Sargent" (USACE 1942). Water spread into an array of wet meadows, freshwater marshes and ponds, willow swamps, and swales, eventually coalescing again into a well-defined channel – the origin of the Pajaro River.

The riparian and aquatic habitats of south Santa Clara Valley exhibited a related range of ecological and hydrogeomorphic variation. Streams entering the valley rapidly sank into the permeable soils of their alluvial fans, creating a network of winter wet/summer dry reaches throughout most of the valley floor. Riparian habitat varied along a corresponding gradient from canyon to canyon mouth to the open alluvial plain (fig. 7.6). On smaller streams, a narrow line of trees at the top of the alluvial fan rapidly gave way to occasional trees or no riparian trees. Larger streams rapidly shifted from forest to woodland to open, sycamore-dominated riparian savannas as they reached the valley floor. Subsurface flows supported these sycamore savannas. The extent of persistent summertime fish pools is not known, but it is clear that they were common in at least some areas and supported substantial native fish resources.

On the open valley floor, sediment-rich, high-energy streams such as Uvas-Carnadero, Llagas, and Pacheco created heavily scoured, braided morphology with multiple, frequently shifting channels. Large, mostly unvegetated channel beds and bars with occasional riparian scrub, trees, or groves formed the characteristic riparian habitat. Uvas-Carnadero and Pacheco creeks, perhaps because of their steeper gradient, formed especially wide braided channel reaches. In contrast, Llagas Creek maintained a narrower braided channel along its lengthy alluvial course (still generally wider than 60 m/200 ft). Having deposited much of their sediment load but still with sufficient stream power to maintain a channel, Uvas-Carnadero and Pacheco creeks each underwent an abrupt shift from broad, braided channel to meandering single thread channel on the lower alluvial plain.

Tributary channels were often shallow across the valley (as little as a foot or two deep) and many dissipated completely, spreading into overland flow and groundwater percolation.

Groundwater reemerged at the base of the Uvas-Carnadero, Llagas, and Pacheco creek fans, as the streams ceased building natural levees and spread their remaining fine sediment into broad willow groves and freshwater marshes. Lower Pacheco Creek merged into the sag pond of San Felipe Lake, but (other than the large component of open water) the surrounding wetland mosaic was equivalent to wetlands at the base of Llagas and Carnadero creeks.

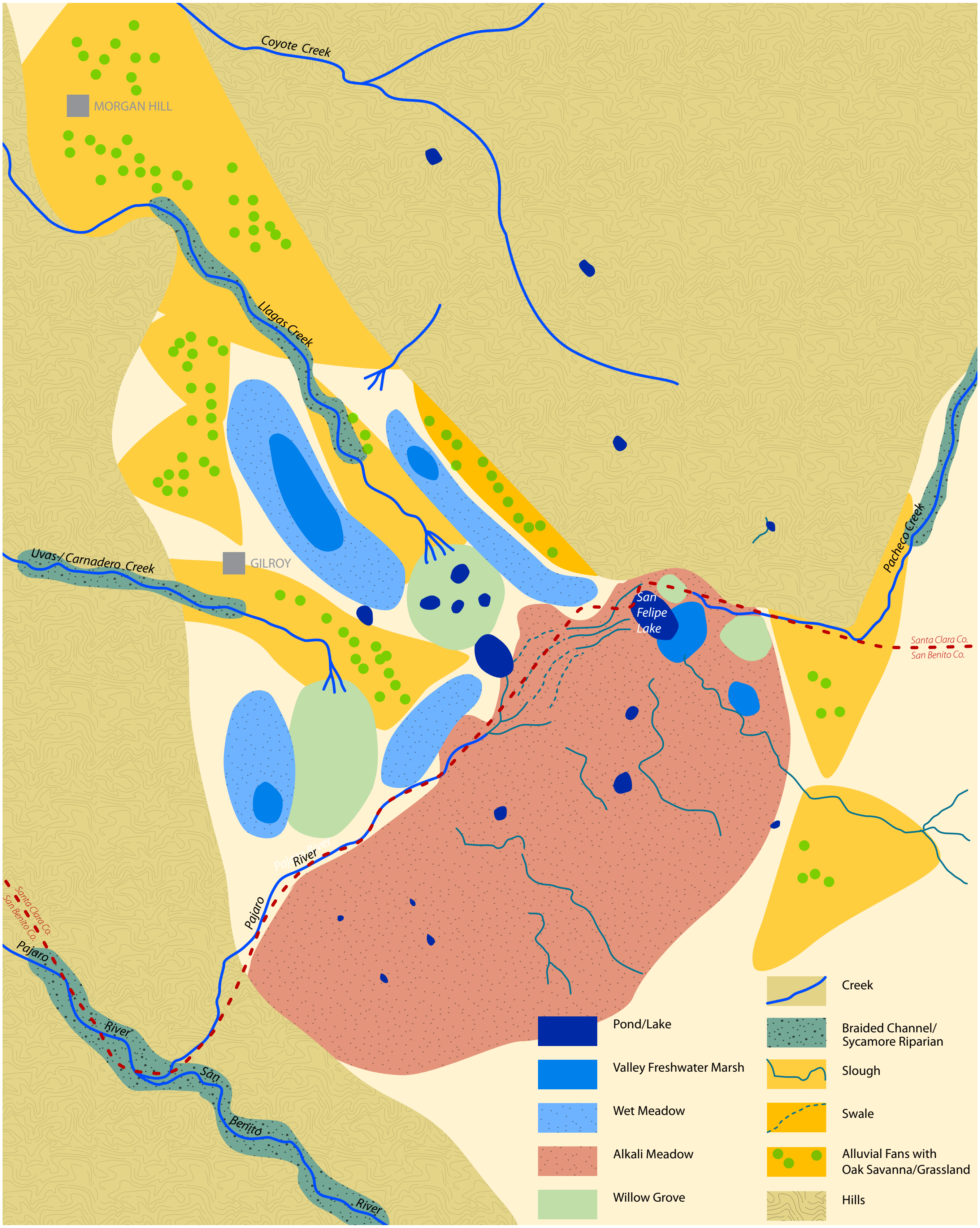


Figure 7.5. Conceptual model of landscape-level habitat patterns in south Santa Clara and north San Benito counties prior to significant Euro-American modification (simplified and not to scale).

Figure 7.6. A photograph titled "Fishing on Llagas Creek," illustrates a dense riparian canopy with alders in a rocky stream bed on upper Llagas Creek. (Unknown ca. 1896d, courtesy of History San José)

Substantial effort went into creating artificial channels through these wetland areas, including lower Carnadero and lower Llagas creeks (Stimson 1944):

> The land was at that time covered with a dense growth of willows. Mr. Rea cleared the land and opened a channel for Carnadero Creek... (Shortridge [1896]1986)

> In spite of a drainage ditch more than a mile in length which was constructed recently, the water table in this vicinity is usually within 3 feet of the surface during the drier part of the year, and during the rainy season the surface is inundated in places to a depth of 6 feet. Sedges and water loving plants are the main vegetation... (Cosby and Watson 1927a, describing lower Llagas Creek)

Downstream of these natural sediment sinks, a completely different style of stream formed – the densely wooded, meandering, perennial Pajaro River. The Pajaro River received perennial base flow as groundwater that percolated through the braided channels and alluvial fans of its tributaries and reemerged through the wetlands surrounding the Bolsa. The wetlands acted as sponges, releasing water to the river through the dry season, and maintaining perennial flow likely as far downstream as the San Benito River confluence, at which point its form became dominated by the large, braided river morphology of the San Benito.

MORGAN HILL, SAN MARTIN, AND MID-LLAGAS CREEK

The valley lands from Morgan Hill to San Martin (fig. 7.1) are shaped by the giant cone of Coyote Creek's alluvial sediment, which radiates outward from the creek's canyon mouth near Anderson Dam. The southern half of Coyote's alluvial fan extends southward, a remnant of when the creek flowed south to the Pajaro River

(Branner 1907). The well-drained Arbuckle gravelly loams, Pleasanton loams, and Pleasanton gravelly loams east of Morgan Hill supported dense oak woodlands.

Morgan Hill oak woodlands

> *"Morgan Hill . . . is situated in a beautiful grove of oaks"*
>
> — SHORTRIDGE 1896

GLO surveyor Richard Howe (1851) described this area as a woodland, containing "low, mossy oak timber," and landscape photography also shows closely spaced valley oaks (figs. 7.7 and 7.8; see Chapter 6). Progressing south toward the finer soils of the valley floor and higher groundwater tables, overall oak density decreased, making smaller woodland patches notable features within the larger grassland landscape. Unlike other fertile areas in the Santa Clara Valley, the land between Morgan Hill and Gilroy was subdivided fairly late (1892-3; Shortridge [1896]1986). Harrison (ca. 1888) reported:

> ... on the eastern side of the valley, is a large area of virgin soil, beautiful level valley land, covered with wide-reaching oaks, ably fine vine land, and is the least populous of all the Gilroy section of country. There are 40,000 acres of land here upon which there are less than a dozen residences.

As a result, large areas of the original oak woodlands still remained when landscape photography became more common in the 1890s, as film replaced fragile glass plates.

Figure 7.7. The 1896 view looking north along Monterey Road on July 25 shows some of the oaks remaining at that time (A). While few can be seen in the image from the same vantage point today (B), several large old trees are still found in Morgan Hill and younger live oaks can be seen in median strips along Monterey Road. Knob Hill, the vantage point for several of the Morgan Hill landscape photographs in Chapter 7, is on the left, behind the church which can be seen in both photos (a). (A: Unknown 1896, courtesy of the Morgan Hill Historical Society)

"We camped under some beautiful oaks, near a house, where we got hay and water...I only wish you might have beheld the scene. Five large oaks, their branches festooned with lichens, are our canopy. The bright fire lights up their trunks and foliage and the group around. The moonlight lies soft on the plain and lights up the black mass of the peak, Ojo de Agua de la Coche, that rises back of the camp, its black outlines sharp against the blue sky."

– WILLIAM BREWER, 1861

Figure 7.8. The 21-mile house, located at the corner of Monterey Road and Tennant Avenue, served as a stopping place since it was built in 1852 for travelers going between San José and Monterey (it was so-named because it was 21 miles from one town to the other). Many travelers recorded spending a night or two in the location, under the large oak trees shading the spot. In particular, renowned geologist William Brewer described the scene (transcribed above). The house was removed in 1917.

Wet meadows east of Llagas Creek

In contrast, a large zone of Cropley clay soils on the eastern extreme of the valley floor (and smaller pockets of other wetland-associated soils south of this zone around San Martin) indicate wet meadows with few oaks. This is corroborated by results from the correlations using 1939 relict oaks.

In particular, in one area east of Llagas Creek beginning around where the creek turns sharply south along the valley floor, a series of aguajes (a potable water supply or spring) dotted the valley floor. The aguajes, shown on an early (1840s) map of the area, appear to have been part of a larger wetland complex (fig. 7.9). This map suggests that the aguajes were surrounded by (undefined) wetland vegetation and included multiple ponds. The top aguaje on this map is labeled "aguaje chupadero." Gudde and Bright (1998) defines "chupadero" as "a brackish pool where animals come to drink," implying that at least one of the aguajes shown was saline.

These aguajes appear to coincide with the wet meadow soils mapped by Cosby and Watson (1927a) alongside Llagas Creek.

Figure 7.9. This 1840s diseño shows a series of aguajes (a potable water supply or spring) along Llagas Creek (here labeled "Arroyo Seco," or dry creek) as it turns south along the valley floor. One is labeled "aguaje chupadero," indicating saline conditions. Unlabeled vegetation is shown surrounding the aguajes. (U.S. District Court, Northern District [184-?]d, courtesy of The Bancroft Library, UC Berkeley)

Creeks and wet meadows

Many streams tributary to Llagas Creek were discontinuous, and even those with recognizable channels were extremely shallow. A number of broad swales can be identified in early aerial photography. Even Llagas Creek northwest of San Martin was relatively shallow, "intrenched [sic] from 5 to 10 feet below the surface of the soil" (Cosby and Watson 1927a). Many of these streams have remained extremely shallow, or have only been modified in the past few decades. Cross-sections and profiles of streams such as Center Creek, Maple Creek, and Tennant Creek made in 1975 show channels typically incised just 0.3-1 m (1-3 ft) below the adjacent valley surface (fig. 7.10; USACE 1975).

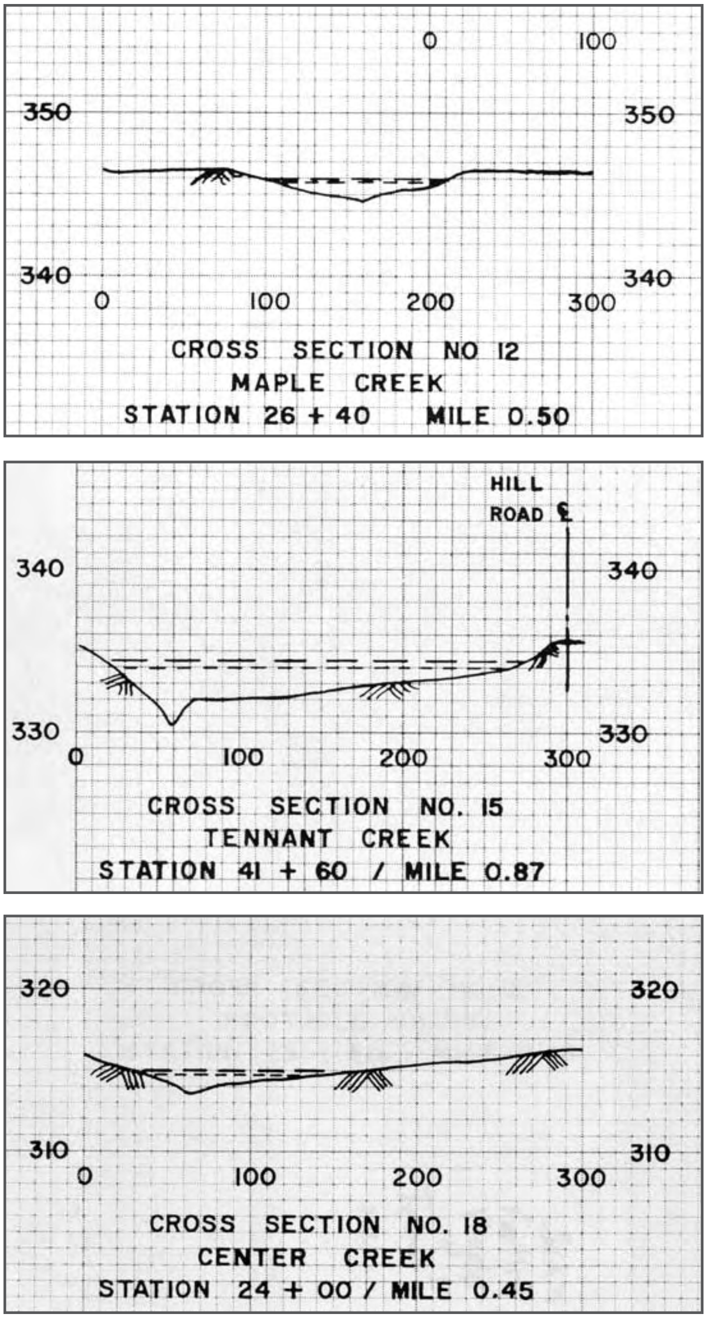


Figure 7.10. Creeks such as Maple, Tennant, and Center had broad and shallow cross-sections in the wet meadows east of Morgan Hill. In places, they could be considered sloughs or swales (cross sections have 10× vertical exaggeration). From USACE (1973).

Poza de las Llagas

Just north of the low spur of hills jutting into the valley north of San Martin, and west of Monterey Road, was the "Poza de las Llagas" (the las Llagas pool). The place was so central as a stopping point and water source along Monterey Road that it was also referred to simply as "Las Llagas" (referring just to the poza, not the entire creek; fig. 7.11):

> In speaking of this place many persons called it the "Las Llagas" but it is not the Arroyo de las Llagas which is understood when it is spoken of - it is in the arroyo, but it is one place, known by the name of "Las Llagas" to distinguish it from the arroyo at large, and it has been distinguished ever since I was a little boy (Pinto 1855b).

The Posa de las Llagas was also referred to as a well or a spring (Castro 1855b). It appears to have been a groundwater-fed, in-stream, perennially flowing pool. It was located "immediately above the pass called the Puerto Suelo [portezuela = pass or gap in hills]" (Castro 1853). This portezuela was likely the low topographical point (near the intersection of California and Coolidge Avenues) that served as a pass over the San Martin spur.

The poza was valued as a stopping place with a perennial source of fresh water, used as a campsite and for clothes washing by travelers and rancho residents:

> There is water on the place (Las Llagas) all the year around and people traveling about there were in the habit of camping there (Pinto 1855a)

> ...it was a stopping place and there was water there all the year round and people washed clothes there – it was called the "Posa de las Llagas" (Castro 1855b)

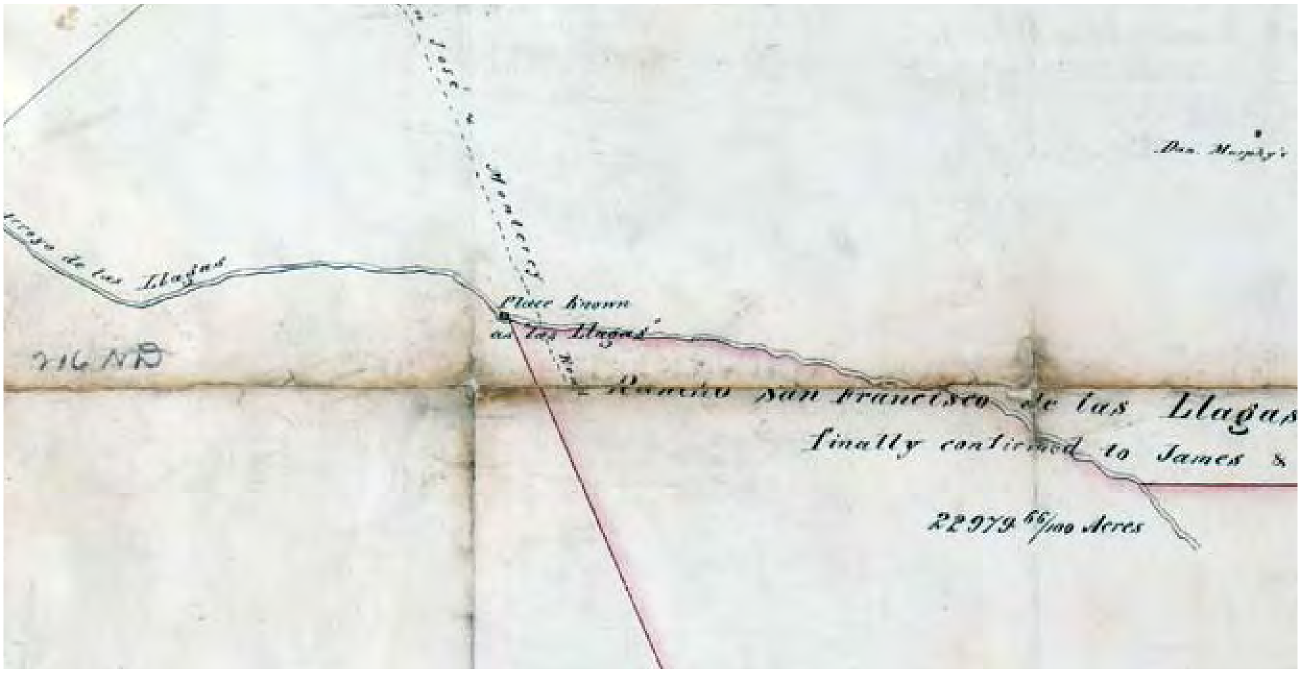


Figure 7.11. This early map shows the renowned pools (here labeled "Place known as 'las Llagas'") on Llagas Creek near the historical El Camino Real crossing. (U.S. District Court, Northern District 1860, courtesy of The Bancroft Library, UC Berkeley)

Figure 7.12. Llagas Creek, ca. 1908. This postcard shows the creek flowing in the winter with a sycamore without leaves on the bank. Gilroy Hot Springs Road presumably refers to present-day Leavesley Road. (Unknown ca. 1908 (Neg. no 13764), courtesy of the California Historical Society)

GILROY, UVAS CREEK, AND LOWER LLAGAS CREEK

Further south, beyond the dominant effect of the Coyote Creek fan, the valley was shaped by smaller alluvial fans from tributary creeks and narrow strands of higher land following present and former natural levees of Llagas Creek. For example, lowlands lay along both sides of the present Llagas Creek position, forming long wetland strands stretching for several miles. Old Gilroy was located on a natural levee of Llagas Creek, but the city was moved to even higher ground along the Carnadero to the east around 1869. A lobe of Carnadero Creek's alluvial sediment blocked Miller Slough-lower Llagas Creek's drainage into Pajaro River, causing even more extensive wetlands to form. Llagas Creek shifted from a braided channel to a meandering, single thread channel (fig. 7.12), before spreading into sloughs and distributaries in the vicinity of Pacheco Pass Road.

Seasonally flooded wet meadows covered large areas. These areas stayed relatively moist into the summer and were central to Gilroy's rise to prominence as a center of California's dairy industry (1.3 million pounds of cheese/year in 1896; 20% of the state's production), which was ascribed to the productivity of the "native meadow grasses" in the wet meadows south of the city. In 1896, Shortridge [1896](1986) recorded that "Gilroy's principal product is cheese, the succulent grasses which flourish along the creeks and in the low lands at the confluence of the several streams in the center of the valley, having early brought about the development of the industry."

Gilroy oak woodlands and sloughs

Around 1869, the current town of Gilroy was established west of Old Gilroy at a site with relatively dense oak woodlands. The combination of shade trees and well drained soils was ideal for settlement.

> *"[Gilroy] was formerly covered with groves of magnificent oak trees, many of which yet remain, giving to the locality a natural park-like appearance...The streets are broad, and the natural drainage, owing to the porosity of the soil, is excellent, so that the streets are neither muddy or sticky in the winter, and in summer they are kept well sprinkled."*
>
> – SHORTRIDGE 1896

The townsite occupied slightly higher ground with shallow, flood-prone drainages, including Miller Slough, on either side. This characteristic was noted by a traveler in 1874: "The country around Gilroy seemed low and flat, as though it might be easily undulated [sic] in the rainy season" (Likins 1874). There is some suggestion that sloughs in the vicinity of 8th St. were overflow channels from Uvas-Carnadero Creek. Surprise flooding of the otherwise innocuous-appearing sloughs has led to decades of flood protection efforts.

> Uvas Levee.—...the slough running easterly from the Uvas, became so swollen during the high stage of water [last winter], that it overcame its embankments and flooded the extreme southern end of our town, and wending its way toward San Y Sidro [sic], spread out into a vast lake inundating hundred of acres of valuable land and sweeping away fences, bridges, &c., to the damage of the entire community. ... The slough at the southern end of town became a little too full for its capacity, and quite a current broke over the northern bank and started "up town," crossing Monterey street south of the Swiss Saloon to the railroad track, thence in every direction indicated by gravity. The main slough washed away the bridge at the end of town, and then went rushing madly along towards San Ysidro, finally emptying itself upon the broad plain, which during the afternoon of Wednesday, looked like a great lake....We do not wish to see the travel diverted from the main street again, or lives imperiled in attempting to cross the main slough at the south end of Monterey street, when swollen by a mad current of water, which was the case last Winter. (November 27 1869, Gilroy Advocate 1869c)

Miller Slough historically drained into the wetlands alongside lower Llagas Creek. Its lower portion has been disconnected from its upper portion, which was diverted directly into Llagas Creek and renamed West Branch of Llagas Creek:

> Several diversion alignments are included in the proposed plan. The West Branch of Llagas Creek and Miller Slough will be diverted around the City of Gilroy to avoid costly channel improvement work through urban areas. Miller Slough will also be diverted around the city of Gilroy to avoid costly channel improvement work through urban areas. Miller Slough will also be diverted into Llagas Creek approximately 0.3 mile above the Pacheco Pass Highway, and a channel will be constructed to take flows from Little Llagas Creek into Llagas Creek approximately 0.3 mile above U.S. Highway 101. (Division of Soil Conservation 1966)

Uvas-Carnadero Creek

While larger streams such as Bodfish and Little Arthur appear to have connected directly into the Uvas-Carnadero mainstem, many smaller tributaries discharged into their alluvial fans and probably only entered the creek as sheet flow during floods. The stream exhibited distinct morphology and riparian canopy architecture along its length, as discussed in Chapter 4. While there is only limited evidence for historical channel depth, downstream in the single thread reach an unfortunate accident suggested that the creek was quite deep. A man named Charles Taylor, working on the Carnadero Bridge (presumably at Monterey Road, or possibly the railroad crossing) in July 1874, died after falling "into the dry bed of the creek, a distance of 30 or 40 feet" (San Benito Advance 1874).

Some information about finer-scale riparian plant communities is provided by memories from Ascención Solorsano:

> We used to make swings of the runners of the chilicote at Las Uvas Creek at Gilroy. It used to grow there way up to the top of the cottonwoods. (Harrington 1929)

> The uvas silvestres [wild grapes] are also called uvas simarronas and uvas broncas, lots of them grow at Uvas Creek at Gilroy, they climb way to the tops of the cottonwoods and willows…Over toward the Solis Ranch where we used to camp in the fruit season, Uvas Creek is almost covered with wild grapes and chilicote and yerba del chivato. (Harrington 1929)

Solorsano's descriptions probably refer to the Uvas Creek reaches with denser riparian woodland and more base flow upstream of the Bodfish Creek confluence, where Solis Rancho was located. (This reach was consistently called Uvas Creek historically, while downstream was considered Carnadero Creek.) Historical fishing accounts also commonly referred to these upper reaches, e.g., "…the Uvas and its tributaries furnish excellent trout fishing…" (Harrison ca. 1888; fig. 7.13).

"… Uvas Creek is almost covered with wild grapes and chilicote and yerba del chivato."

– ASCENCIÓN SOLORSANO, 1929

Chilicote (Chilicothe) refers to Coast wild cucumber, a native perennial vine (*Marah fabaceus*) also known as California man-root because of its giant tuberous root (Parsons 1909). Yerba del chivato refers to creek or Western white clematis (*Clematis ligusticifolia*). One of the few early botanical records from Santa Clara County (recorded in 1962 along lower Carnadero Creek between Highway 101 and the willow groves) contains a very similar description of Western white clematis "clamoring over shrubs" (Seeno 1962).

Lower Llagas Creek and wetlands

The lower Llagas Creek region (from around Gilman Road south to the Pajaro River) supported a mosaic of seasonal wet meadow, perennial freshwater marsh, and seasonally dry ponds and lakes. On the flat, low land around Old Gilroy, Llagas Creek spread into a shallow, poorly-defined channel, then into multiple channels traversing the marshy areas. These channels drained through the large willow grove at the bottom of Llagas

Creek into "Pajaro Lake" (Day 1854), a large, seasonal lake connecting the bottom of the Llagas with the head of the Pajaro River.

> *"...the cienega or swamp into which the Llagas flows..."*
>
> – Hoffman 1864

Many people noted the tendency to flood around Old Gilroy. One resident, frustrated by a proposal to build a road from Hollister to Gilroy through the lowlands east of Old Gilroy, wrote that

> The water, or I might term it a moving lake, has been known to be between two and three miles wide, and from thee [sic] to ten feet deep on this proposed road. Dam up this moving lake with a road, culvert it as you will, you cannot make it a road for winter. (Gilroy Advocate 1869a)

Modern Frazier Lake Road, which roughly follows this proposed route, was at this time no more than a dead-end road servicing individual farms.

Hoffman (1864) described the region as "the cienega or swamp into which the Llagas flows." Harrison (ca. 1888) described the general area: "[Llagas Creek] follows its channel to a point near Old Gilroy, three miles south-east, where it finds a low, flat country, and spreading out over many hundred acres, forms a tule swamp." As late as the 1950s, the lower reaches of Llagas Creek were poorly defined and flood-prone: "In this lower section [the last 3.5 mi of Llagas Creek] the channel is not well defined, and the stream overflows quite regularly during flood periods" (Blackie and Wood 1939).

Though it flooded easily, early farmers recognized the potential value of this land for agriculture and dairy production. Coffin (1873) noted that "in the regions receiving the outflow of the Uvas and Llagas creeks, in what is known as 'willow land,' we have a rich, quick, warm alluvium, fine for corn, but especially valuable for gardening purposes." The catch was that the soggy land needed to be drained before it could be cultivated. Harrison (ca. 1888) predicted that since the swamp land around the lower Llagas "can be drained into the Pajaro river, the day is not far distant when it will all be re-claimed; in fact, much of it has already been made tillable." By the 1890s, extensive ditch systems were in place in the Bloomfield Road/Pacheco Pass Road region east of Gilroy to drain this land (Herrmann 1894, Herrmann Bros. 1890).

Miller Slough wetlands

Between Gilroy and Old Gilroy, the landscape was dominated by expanses of perennial freshwater wetland and seasonal wet meadow on the Dublin clay adobe and Dublin clay loam soils which covered the area. Surveyor William Lewis (Lewis and White 1853, Lewis 1853a) illustrates the westward transition from willow grove to the east and freshwater marsh to the west: on the east side of Llagas Creek, he notes "swamp" and "willow swamp" (that is, willow groves), and on the west side of Llagas Creek he notes "marsh and swamp" (that is, willow groves and marshes). This is consistent with our mapping, which shows willow grove on either side of the historical Llagas Creek channel and large swaths of freshwater marsh exclusively on the western side of the Llagas. This band of marsh covered much of the large areas of wetland soils (Dublin adobe, Dublin clay, and muck and peat) between Gilroy and Old Gilroy. Supplied by Miller Slough and Llagas Creek overflow, this area extended from just south of Gilman Road to about Carnadero, crossing Miller Slough and Pacheco Pass Road.

To the north, seasonally dry wet meadows dominated the landscape. Day (1854), surveying the region in June, described the area's seasonality. He noted that it was "meadow land, wet in winter," would be "in wet weather, among green grass" and that there was "no timber except for a few oaks round Martin's house."

Figure 7.13. Uvas Creek, which historically referred to the reaches upstream of the Bodfish Creek confluence, is shown as a relatively densely vegetated, perennial stream in these two images. "Scene on Uvas Creek" (A), taken near Adams School in the vicinity of Adams-Chitactac County Park, shows large pools in the foreground and background, with a shallow riffle in between. An undercut alder can be seen on the bank at left. (A (Unknown ca. 1930) and B (Unknown ca. 1912b): courtesy of the Gilroy Museum)

Lower Llagas willow thicket

> *"From this point I meandered down the Arroyo de las Llagas through a dense willow thicket..."*
>
> – WALLACE 1858

To the east of the perennial freshwater wetlands, around the current location of the lower Llagas Creek channel, a vast willow grove (approximately 280-320 ha/700-800 ac) extended from Old Gilroy (just south of Pacheco Pass Road, and east of the modern Llagas Creek channel) south past Bloomfield Avenue (fig. 7.14). The northernmost extent of the willow grove is just below Pacheco Pass Road, indicating that this segment of the road was constructed to circumvent the northern edge of the willow grove. Quentin Ortega and John Gilroy, the owners of the two San Ysidro ranchos, built their houses on a tongue of slightly higher, better drained Yolo silt loam on the edge of this willow thicket, about a tenth of a mile from where Dyer (1861) recorded the "edge of a dense willow thicket" (fig. 7.14).

Early surveyors recorded traversing a "dense willow thicket" (Wallace 1858, Upson 1867(?)). This willow grove, unlike the sausal at the lower end of Carnadero Creek, had inclusions of freshwater marshes and ponds in addition to the dense willow thickets. McDonald (1852(?) b) calls the region "willow and tule swamp" (rather than just "willow swamp," as at the bottom of Carnadero Creek) and depicts a mosaic of the three habitats (see fig. 5.8). Dyer (1861) also noted a transition within the willow grove (remarkably consistent with that mapped by McDonald six years earlier) between willow thicket and tule-filled freshwater marsh. He records the point where he exits the willow grove and enters "a tract of low marshy land covered with tule and flags."

Multiple sources indicate that Llagas Creek flowed through at least part of the large willow grove at its base. Salvio Pacheco (1861) testified that "the arroyo de las Llagas emptied in the tular, and from the there the waters are run into the Pajaro"; José Castro (1855a) called it "a willow swamp where Las Llagas overflows." Well into the willow grove, surveyor Dyer (1861) noted that the channel was "24 links [5 m/16 ft] wide," indicating that the channel was wide well into the willow grove. These testimonies support both that Llagas Creek entered the willow grove a substantial distance before spreading, and confirms the image of the area as a willow grove with tule patches within it.

Soil surveyors Cosby and Watson (1927a) noted the inherent flooding challenges associated with the alluvial topography, and the limited success of drainage efforts:

> During comparatively recent times, Llagas Creek has been somewhat dammed off from its natural outlet by the deposition of alluvial sediments by Carnadero Creek, and a condition of very poor drainage has developed. In spite of a drainage ditch of more than a mile in length that was constructed recently, the water table in this vicinity is usually within 3 feet of the surface during the drier part of the year, and during the rainy season the surface is inundated in places to a depth of 6 feet. Sedges and water-loving plants are the main vegetation, and two bodies of muck and peat have accumulated...a considerable tonnage of meadow grasses are cut for hay on the better drained spot. The greater part of this region can only be used for summer pasture for dairy cows.

Pajaro Lake and other seasonal lakes

At the bottom of Llagas Creek, at the southernmost extent of the willow grove, many early surveyors mapped a large (over 40 ha/100 ac at its greatest extent) lake. Though the western edge of the lake was followed by some surveyors to mark part of the western boundary of the San Ysidro (Ortega) Rancho, other surveyors (notably those surveying in late summer) went straight through a dry plain where others noted a lake (see fig. 5.10).

Across seasons, the lake fluctuated widely in extent, even drying up in the late dry season, indicating that it was

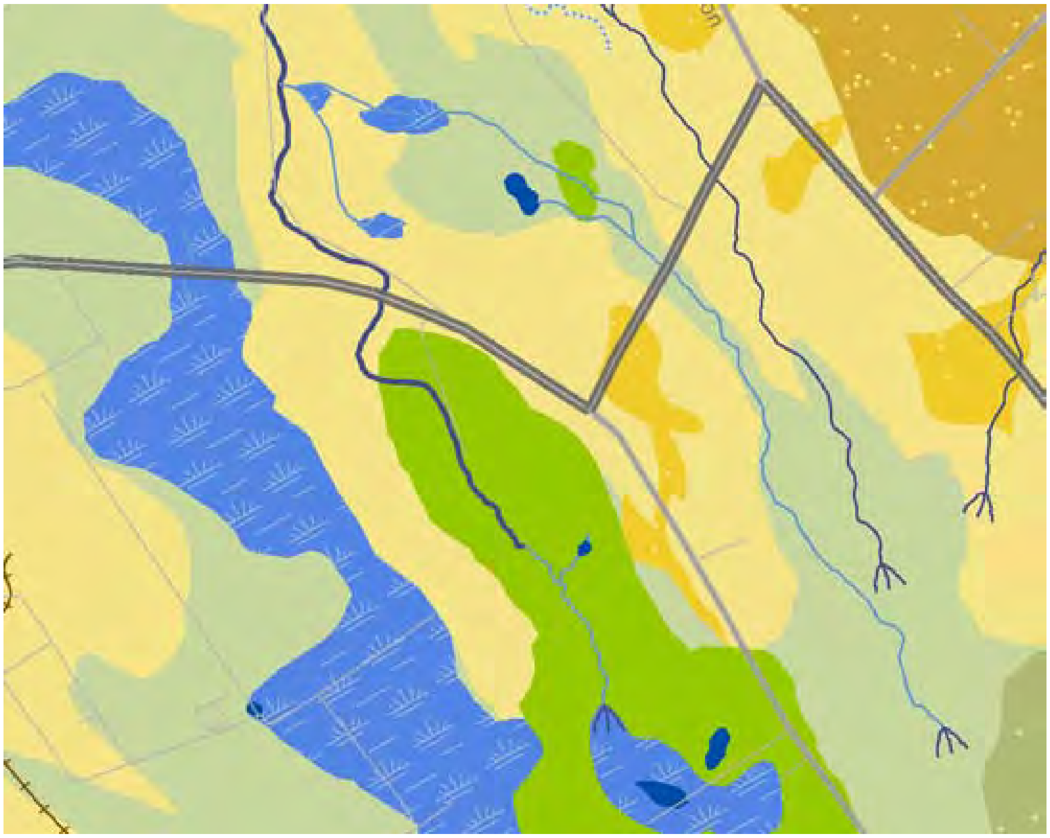


Figure 7.14. The GIS of historical habitats here shows the wetland mosaics surrounding Llagas Creek at Pacheco Pass Road. Immediately upstream of the road, the creek (flowing south in the center of the map) overflowed into the Jones Creek drainage. Downstream of the crossing, it spread into willow groves and freshwater marshes. (See inside front cover for map legend.)

an extremely shallow feature (consistent with the area's topography). In January, Hardenburgh (1872) recorded the "end of willow thicket where the water begins to spread out into a lake" about a quarter mile north of Bloomfield Road. In March, Wallace (1858a) surveyed the San Ysidro (Ortega) Rancho, mapping the lake at approximately 45 ha/110 ac. In April and May, Wallace (1858b) conducted a similar survey, this time for the adjoining Las Animas Rancho. Only one or two months after the March survey, the lake had shrunk considerably: Wallace mapped it at just over 20 ha/50 ac, about half of its previous size. In June 1854, there was still enough of a lake present for Day (1854), who called it "Pajaro Lake," to sight to it from a low hill on the eastern side of the valley near San Ysidro Creek, about three miles away.

By September, however, surveys across a variety of years no longer recorded any lake at all. Dyer (1861) noted only "a level plain" where the lake would have been. Lewis (1850b), another September surveyor, also made no mention of it nor deviated from his survey line to go around the west bank, only describing the general area around the lake as "low marshy ground."

At its largest mapped extent, Pajaro Lake was approximately the same size as historical San Felipe Lake. However, Pajaro Lake was not recorded on any diseños depicting the area (e.g., McDonald 1852(?)c; U.S. District Court, Northern District 1873a,b), and none of our narrative sources mention it. This supports the model of a seasonal lake of variable size that did not serve as a cultural resource or landmark of note in the same way as did San Felipe Lake.

The nature of the connection between the Pajaro River and Pajaro Lake remains unclear. Some maps (e.g., Wallace 1858a; U.S. District Court, Northern District 1860; Geological Survey of California 1873) show the lake as the beginning of the Pajaro, with a clear connection between them (fig. 7.15). This would fit well with Day's (1854) label of "Pajaro Lake" - the role that San Felipe Lake, not Pajaro Lake, plays for the Pajaro River today. However, Lewis (1850b), describing the survey of the Las Animas Rancho, makes no mention of a connection; rather, he follows a "small tributary" off the Pajaro to the tributary's head before heading northwest through the "intervening marshy ground" where others recorded the lake. This small tributary at the head of the Pajaro was likely the "Arroyito or Aguage [sic] de los Cuatro Sauces" —the little creek or spring of the four willows, named for the landmark grouping of four willow trees along the Pajaro River and mentioned in the San Ysidro (Ortega) land grant case file (Gonzales 1833). It is possible that in some years or seasons, the lake and river were not connected, while at other times they were connected through a shallow channel or system of swales.

Though Pajaro Lake was by far the largest seasonal lake in the lower Llagas area, it was not the only one. Many small lagunitas dotted the area, occurring in larger pockets of freshwater marsh and willow groves (see fig. 7.2). One such lagunita recorded a corner of the boundary line between the San Ysidro (Gilroy) and Las Animas ranchos. It similarly was recorded as dry or of variable size, dependent on the season. Where winter surveyors (e.g., Hargenburgh 1872) noted a lagunita, a survey likely conducted in late summer or early fall noted a "small dry lagunita" (Upson 1867(?)). Hoffman (1864) called it a "small lagoon which spreads out to the marsh of the lands of the late Ignacio Ortega," conjuring a picture of a shallow lake only slightly lower than the marsh around it. By 1894, the spot was labeled only as "The Rock Corner" (after a boulder thrown into the lake to mark the corner in 1850; Herrmann 1894). It is likely that by this point, the extensive draining of the area had made the former lake a permanently dry feature.

CARNADERO CREEK

At its downstream end, Carnadero Creek spread into a large willow grove before joining the Pajaro River east of its current confluence. This area (south of Gilroy and

Figure 7.15. This map, from a March 1858 survey (Wallace 1858a), shows a schematic version of the connection between Pajaro Lake and the head of the Pajaro River. Here, the lake is shown as a connecting feature between the mouth of Llagas Creek and the origin of the Pajaro River. (Courtesy of The Bancroft Library, UC Berkeley)

north of the Pajaro River) was characterized by a mosaic of willows, freshwater marshes and ponds, and multiple channels of the Carnadero and other small creeks from the west spreading out into the willows.

Pozas de Carnadero

Several perennial ponds west of El Camino Real and south of Carnadero Creek were an early 19th-century landmark, and provided the site for Mariano Castro's home on the Las Animas Rancho. Many diseños (e.g., McDonald 1852(?)a,b,c; U.S. District Court, Northern District 1873a,b) show multiple ponds interspersed in a creek channel, while others (e.g., U.S. District Court, Northern District [184-?]c, U.S. District Court, Southern District [184-?]c) show a single, proportionally large "Poza," the latter indicating adjacent wetland vegetation and trees (fig. 7.16). One map names the poza "Posa Animas" (U.S. District Court, Northern District 1861). The pozas were probably large perennial pools on Gavilan Creek, which was called "Arroyo de las Pozas." Interestingly, there is an anomalous patch of clay soils along the creek here (Cosby and Watson 1927a). It is possible that, as in other parts of the Santa Clara Valley, the fine-grained soils formed a dam to groundwater movement, causing near-surface groundwater to emerge at the surface. Little or no trace of the creek and these features is visible today.

Carnadero willow grove

The historical spreading of Carnadero Creek into a willow grove in the vicinity of present-day Bloomfield Avenue is well-documented by numerous sources. McDonald (1852(?)a,b,c) and Thompson and West (1876) referred to the feature as a "Willow Swamp," while earlier Mexican-era maps (e.g., U.S. District Court, Northern District 1873a,b) used the equivalent phrase "Sausal." Lewis (1851) set a point in "the Willows." GLO surveyor Hardenburgh (1872) crossed the feature, defining its margins with corresponding points labeled "Enter swamp and willows" and "Leave swamp and willows." This outer boundary encompasses the earlier sources despite its later date, suggesting that it took decades to fully remove the feature. A central portion of the willow grove was mapped as "Muck and peat" by the 1923 USDA soil survey (Cosby and Watson 1927a), reiterating its wetland origin.

Figure 7.16. A detailed drawing of the "Poza de Carnadero" suggests surrounding wetlands and trees, as well as a direct connection to the creek. (U.S. District Court, Northern District [184-?]c, courtesy of The Bancroft Library, UC Berkeley)

Based on their own historical research, Shortridge ([1896]1986) later described "the rich delta land at the mouth of Carnadero Creek, near Gilroy… at that time covered with a dense growth of willows," while Broek (1932) reported "a willow covered marsh, formed by the Carnadero Creek which spread its water over a flat basin."

> *"Here a willow covered marsh, formed by the Carnadero Creek which spread its water over a flat basin, was drained and a dairy started on the cleared land."*
>
> – BROEK 1932

There does not appear to have been a singular well-defined Carnadero Creek channel through the willow grove recognized in the mid-19th century, before Samuel Rea "opened a channel for Carnadero Creek" (Shortridge [1896]1986). However, there were likely multiple smaller channels defining flow paths through the willow grove. Lewis (1851) recorded a point just north of the willow grove as "the point where the 'arroyo del Carneadero' begins to branch into several channels," implying that multiple, smaller channels existed at least toward the head of the grove. Herrmann (ca. 1870) confirms this, showing a number of small distributary channels or sloughs spreading through the willow grove from the mouths of Carnadero and Gavilan creeks (fig. 7.17). Thompson and West (1876) also suggest the presence of somewhat defined drainage channels, albeit discontinuous or partially occluded by vegetation. While Shortridge implies that Rea constructed a channel in the 1860s, multiple sinuous or discontinuous channels are shown by maps to the 1870s. As late as 1908, Carnadero Creek is shown with multiple sinuous channels through the former willow grove (McMillan 1908(?)). The USGS quad (1917, surveyed 1915) finally shows a single, relatively straight channel through the area.

The willow groves also encompassed what are now considered the lower reaches of Gavilan and Tick creeks, extending west across the present-day railroad alignment. Smaller open water pond areas and tule marshes were probably found within the larger willow swamp. In fact, a relatively large freshwater marsh component is strongly suggested by historical evidence on the southwestern margin of the willow grove near the mouth of Tick Creek. There was a well-recognized ciénega shown by diseños of the Rancho Juristac (U.S. District Court, Northern District [184-?]c, U.S. District Court, Southern District [184-?]c; fig. 7.18). This feature presumably led to the name of an 1840s adobe in the vicinity called "La Ciénega" (Milliken et al. 1993). Based upon the relationship of the ciénega to the historic location of the Rancho La Brea adobes, Tar Creek, Tick Creek, and the El Camino Real, the ciénega would appear have occupied the vicinity of present-day Tick Creek near the Southern Pacific railroad crossing and Highway 101. This location corresponds with freshwater marsh symbols shown by USGS (1917) and an area of "Muck and peat" shown by Cosby and Watson (1927a; this category is not common in the map).

Former route of Carnadero Creek

Until sometime in the mid-1800s, lower Carnadero Creek likely followed a dramatically different channel than the one it follows today. In 1880, Healy (1880b, in Milliken et al. 1993) shows the current alignment skirting the eastern edge of the willow grove, which he labeled "New Channel of Carnadero Creek," indicating that it was a relatively recently created main channel. Historical maps and surveys provide some evidence for the route of the old channel.

The earliest maps (Geological Survey of California 1873; U.S. District Court, Northern District 1873a,b) show Carnadero Creek continuing east to the Pajaro River, rather than turning south at Bloomfield Avenue (fig. 7.19). Instead of passing through the willow grove before joining with Tar Creek (as depicted in maps of the 1870s and 1880s), the old channel veered southeast just south of modern Bloomfield Avenue, departing from the current Carnadero Creek channel just south of where Lewis (1851) recorded that "the 'arroyo del Carneadero' begins to branch into several channels." A former meander or oxbow of Carnadero Creek at Bloomfield Avenue, shown by McDonald (1852(?) a,b,c) extending eastward several hundred meters across the position of the present-day railroad, may provide an additional clue to the location where the former channel course deviated from the modern course. It traversed a mosaic of willow groves, freshwater marshes, and ponds east of the railroad tracks before joining the Pajaro River east of the railroad tracks and Bolsa Road.

These historical data suggest that Carnadero Creek spread into a broad array of distributaries at Bloomfield Avenue, supporting willow groves, freshwater marshes, and seasonally overflowed meadows. This evidence corresponds closely with soils data showing multiple lobes of Carnadero Creek's alluvial fan radiating north, east, and south from the present-day Bloomfield Avenue crossing. While the creek has presently been confined to a southerly route, it clearly distributed water over a much broader area historically.

Figure 7.17. This close-up view of the Carnadero Creek willow grove shows multiple internal channels; such features were likely common in willow groves. (Herrmann ca. 1870, courtesy of the Office of the Santa Clara County Surveyor)

At the far end of the creek course, the confluence of the historical Carnadero Creek channel and the Pajaro River is well-documented by multiple GLO surveyors, who noted the confluence as "Carriadero [sic] Creek [joins the Pajaro] from west" (Terrell 1858) and "Canadiro [sic] Creek joins [the Pajaro] from the west" (Hardenburgh 1872). A probable remnant of this alignment is still visible in contemporary aerial photography, in the form of a wooded channel extending about 300 m (980 ft) northwest of the Pajaro just north of the Southern Pacific railroad crossing.

The rest of the historical creek course is less well-documented. Substantial evidence for an array of wetlands and surface drainage extending east from

Figure 7.18. The ciénega, or freshwater marsh, near the mouth of Tick Creek. (U.S. District Court, Northern District [184-?]c, courtesy of The Bancroft Library, UC Berkeley)

Carnadero Creek to the Pajaro River, above the Carnadero willow grove, may provide a clue to the historical channel alignment. A series of elongate ponds with surrounding marsh and patches of willow grove are shown along this general alignment by Herrmann (ca. 1870; fig. 7.20). These may be remnants of wetlands along a defined Carnadero Creek channel, or may be evidence for a diffuse drainage of sloughs and wetlands that formed the bottom of Carnadero Creek. The odd angles of Bolsa Road in this area may have been designed to avoid these wetlands. Portions of the historical creek course may also have been preserved in the shape of a property boundary, shown by Thompson and West (1876) and Herrmann (ca. 1870). The oddly-shaped boundary follows the general trend of the willow groves, marshes, and ponds shown on the Herrmann map, and ends very close to the known location of the historical confluence with the Pajaro River.

While it is possible that the wetland features shown on the Herrmann (ca. 1870) map portray a remnant of a much larger wetland complex, such a feature is not represented on any map, indicating that even when Carnadero Creek flowed toward the southeast the major wetland feature remained the large willow grove to the south of the creek. This spatial pattern is depicted in several diseños (U.S. District Court, Northern District 1873a,b), which show Carnadero Creek flowing to the north of the large willow grove rather than through it (fig 7.19). These maps show the Llagas and the Carnadero joining east of the sausal, indicating that what is now called the Pajaro River (between the mouths of Llagas and Carnadero creeks) was much less clearly associated with the Pajaro River in the mid-1800s.

Figure 7.20. A detail from a ca. 1870 map of south Santa Clara County shows a series of willow groves, ponds, and wetlands northeast of the SPRR line (in red) and Bolsa Road (in yellow). These features likely marked a historical route of Carnadero Creek. A large wetland (indicated by a series of dashed lines) is shown at right. The Pajaro River runs at the bottom of the image. (Herrmann ca. 1870, courtesy of the Office of the Santa Clara County Surveyor)

Figure 7.19. This early diseño shows Llagas Creek (horizontal, at top) and Carnadero Creek (vertical, at right). The large Carnadero Creek willow grove (labeled "sausal") is shown to the south of the old route of the creek. The large willow grove/wetland mosaic at the bottom of Llagas Creek (labeled "sienega [sic]") is shown with a different pattern than the Carnadero willow grove, indicating that the two features had distinct characteristics. Llagas Creek and Carnadero Creek are shown joining east of the Carnadero sausal, indicating that what is now called the Pajaro River – between the mouths of Llagas and Carnadero Creeks – was not associated with the Pajaro in the mid-1800s. (U.S. District Court, Northern District 1873b, courtesy of The Bancroft Library, UC Berkeley)

While it is unclear when the former Carnadero channel was abandoned, it was likely around the mid-to-late 1860s. Healy's 1880 map labels the current alignment as the "New Channel of Carnadero Creek" but does not show the older channel (Healy 1880b, in Milliken et al. 1993), indicating that the change was fairly recent. However, most maps from the 1870s show no trace of the older channel, also suggesting that the change predated those surveys.

Tar Creek

While Carnadero Creek had no historical confluence with the Pajaro River at the location of its modern confluence, historical evidence suggests that Tar Creek joined the Pajaro River in roughly the same location as does the Carnadero today. Hardenburgh (1871) describes the confluence between Sanjón de la Brea [Tar Creek] and the Pajaro River:

> ...on this Rancho, what is known as the "Sanjon de la Brea" takes its rise, and empties into the Pajaro River, near the South East corner of this Rancho; and the <u>mouth</u> of this Sanjon, or Tar Creek, was called by the Californians "Punta del Sanjon de la Brea."

Use of the term sanjón, which can translate as "ditch" but locally seems to more commonly refer to shallow channels or sloughs (e.g., Grossinger and Brewster 2003), is reinforced by the observation that Day (1854) did not note the stream when his GLO survey crossed the area.

Thompson and West (1876) also show no confluence of Carnadero Creek with the Pajaro River. Instead, they show Tar Creek coming down from the west before veering sharply south at the bottom of the Carnadero willow grove to join the Pajaro River (fig. 7.21).

UPPER PAJARO RIVER AND THE WESTERN BOLSA

The Pajaro River was a well-defined, meandering channel from the San Benito confluence upstream to Llagas Creek, but upstream of this point drainage was a series of shallow sloughs, swales, and wetlands. The true head of the Pajaro River was considered to be where waters from Llagas Creek flowed through Pajaro Lake to form the river (Lewis 1850b).

One of the noteworthy characteristics of the river, as shown in early aerial photography and 19th-century maps, is the many small drainages feeding into the main stem downstream of the Llagas confluence. Many sloughs entered the Pajaro from present and former drainages of the Carnadero, as well as small channels carrying

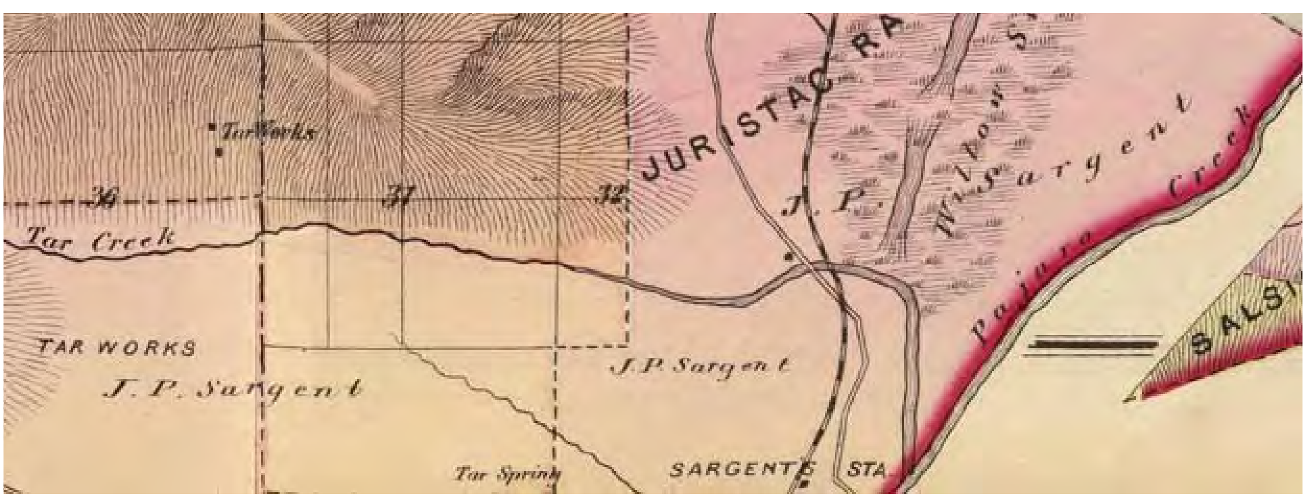


Figure 7.21. Historical evidence suggests that Tar Creek joined the Pajaro River near the present confluence of the Pajaro with Carnadero Creek. This Thompson and West (1876) map shows Tar Creek turning sharply south before joining the Pajaro. Carnadero Creek is shown to the north as broken, wide channels traversing the willow swamp. (Thompson and West 1876, courtesy of the David Rumsey Map Collection)

overflow from the Bolsa to the east. These small channels or sloughs drained the surrounding lowlands directly into the Pajaro channel, suggesting that there were not large natural levees along the channel and that the river was well-connected to its floodplain. Very little trace of these channels is evident in contemporary aerial photography.

> *"Many times we helped her gather pil [Calandrinia ciliata seeds, or redmaids] on the banks of the Pajaro River and on the meadow that adjoins La Hoyoria. She used to make us go into the water to get the little tender roots of the round tule."*
>
> — ASCENCIÓN SOLORSANO, 1929

Additional evidence about riparian habitat on the upper Pajaro mainstem comes from Healy's original survey for the county line, which was defined by the river. Healy (1858a) makes a distinction along the upper Pajaro between reaches with and without "timber." This distinction likely reflects a difference in riparian forest structure, with "timber" referring to larger trees of potential practical use such as cottonwoods, sycamores, and oaks, in contrast to a lower canopy of willow trees and shrubs. Accordingly, in the reaches he describes with timber, Healy notes a sycamore and "double oak"; in the areas without timber the only trees he records are willows. Healy's distinctions may explain the differences among descriptions of the Pajaro's riparian composition. Depending on where travelers crossed, they may have encountered a dense willow canopy or more mixed stands of taller trees.

Upstream of the Llagas Creek confluence, Healy stated that "Timber ceases here" and noted only willows. Willows were reported, apparently as stand-alone small clumps ("a grove of willows," "double willow") upstream along the Pajaro "slough" to only about one-half kilometer (0.3 mi) upstream of the Llagas confluence, with no riparian trees reported along the remaining length to San Felipe Lake. This pattern of sparse small trees continuing upstream of the confluence for several hundred meters and no trees further upstream along the salty sloughs of the alkali meadow is reiterated in 1939 aerial photography.

Day (1854) crossed the Pajaro River near its confluence with Tar Creek in 1854. He recorded both the channel geometry of the river at that point (with 3-5 m/10-15 ft steep bluffs, islands, ponds, and side channels) and the riparian vegetation along the floodplain (mostly dense willows). A detailed diagram of the river's characteristics at this point is shown in fig. 7.22.

Confluence of Pajaro River and San Benito River

The confluence of the San Benito and Pajaro rivers, up to the Pajaro River just upstream of the confluence to Sargent, has long been a place of note for local residents. Long before the construction of Highway 101, this stretch of river was crossed by native inhabitants, Spanish explorers, and Mexican and American settlers traveling from the San Juan Bautista area to points north of the Pajaro River.

> *"There were many baptisms in the Pajaro river, at its junction with the San Benito river."*
>
> — MYLAR 1929

The confluence itself covered a wide area, including an island in its center and a deep pool (fig. 7.23).

> *"...they used to fish at night, and the fish would come to the top of the water, so they could even catch them with their hands, they used to fish more at night than in the daytime. That was at La Poza, where the Sargent [Pajaro] River joins the San Benito. That river used to be very deep, it has been drying up ever since the time that I was born."*
>
> — ASCENCIÓN SOLORSANO, 1929

The large pool at the confluence of the Pajaro and San Benito Rivers was called "La Poza" or the "Poso de Sanchez" in the 19th century (Harrington 1929, Pierce 1977). Over the historical record, the large, deep pool was used a gathering place for a variety of community activities. Ascención Solorsano recalled that "they used to fish at night" on rowboats at the pool (Harrington 1929). According to local historian Marjorie Pierce, the Larios family would go on outings to the pool to swim and pick blackberries during the summer (Pierce 1977). The area was used for baptisms (Mylar [1929]1985), and the sandy beach at the confluence was the site of picnics (Pierce 1977). After the San Juan Bautista Mission was established, the island at the confluence was the site of a ranchería—called "Ranchería de la Islita"—for Ohlone who had been brought into the Mission (Milliken n.d.).

The Pajaro River shifted in morphology and ecology at the confluence with the San Benito River, from a sinuous,

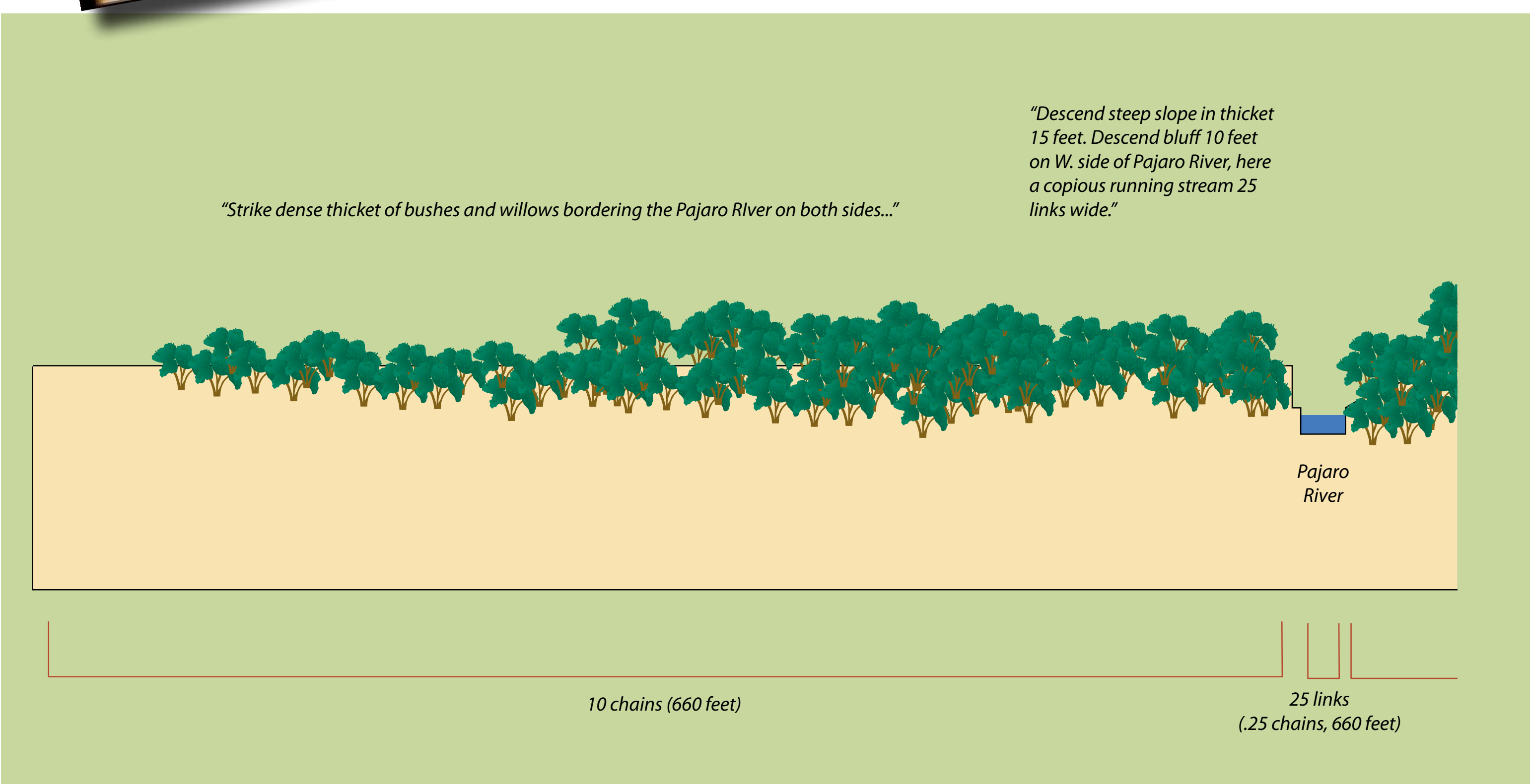


Figure 7.22. Riparian floodplain characteristics of the Pajaro River in 1854, as per Day's 1854 survey notes (above left)

wooded, single thread channel to a broad, braided channel. Stimson (1944) discusses the major effect the large sediment supply from the braided San Benito River channel had on the Pajaro:

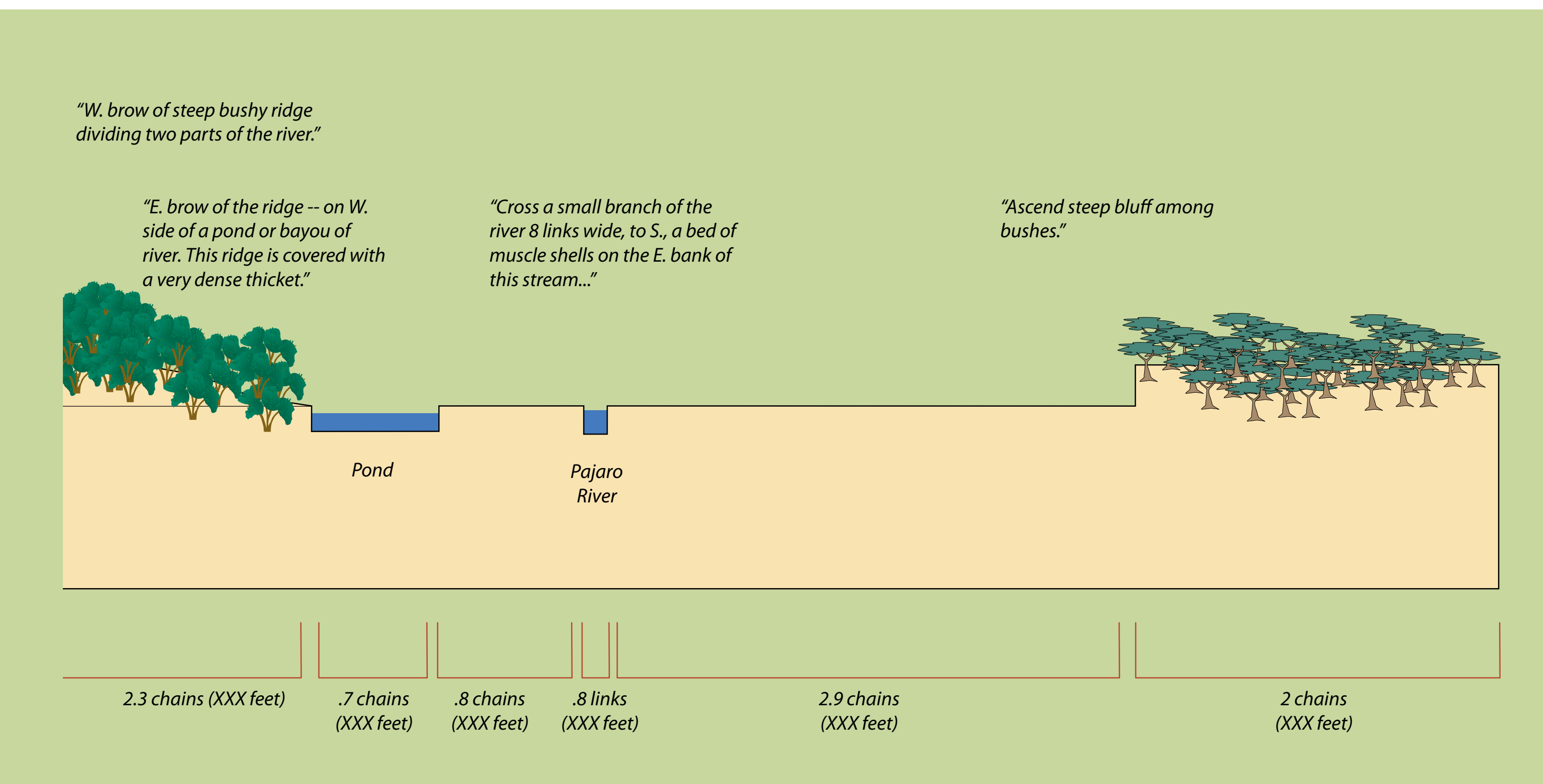
> Great quantities of silt carried in the flood discharges of these streams are deposited in the channel of the Pajaro River downstream, reducing its capacity until discharge from the upper Pajaro River clears the channel again. During the summer months, these sand bar deposits at the mouth of the San Benito River act as a control upon the water level in the Pajaro River immediately upstream.

Sargent's Station

Further upstream along the Pajaro River was Sargent's Station (or simply Sargent), located at a historical crossing of the Pajaro River (which became Monterey Road crossing). Pedro Font, traveling with the second Anza expedition in 1776, wrote that the party came up from near the mouth of the Pajaro River to cross at Sargent because the river was "somewhat miry and much more so farther down...the Páxaro [sic] River farther down is so miry that it is unfordable" (Bolton et al. 1930). Sargent was often cited as the western extent of the Soap Lake floodplain.

> *"There used to be so many flowers at Sargent that it looked like a flowery carpet. There was a lot of cebollín del campo [wild onions] and cilantro and cacomites [brodiaea]"*
>
> — ASCENCIÓN SOLORSANO, 1929

In the late 1800s, Sargent was a popular picnicking spot along the Pajaro: "half-shaded by over-reaching willows, furnishing a cool and secluded spot for boating and fishing" (Harrison ca. 1888). When the bridge across the



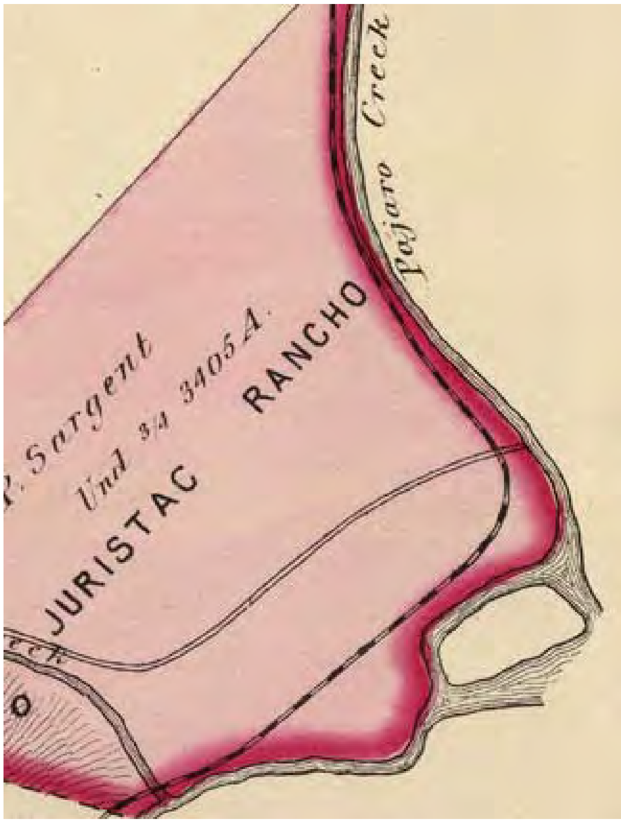


Figure 7.23. This 1876 map detail shows the island at the confluence of Pajaro "Creek" and the San Benito River. This island, and the associated pool, was the site of picnics, fishing expeditions, swimming trips, and baptisms. (Thompson and West 1876, courtesy of the David Rumsey Map Collection)

Pajaro was rebuilt and realigned in 1941, Sargent's station became inaccessible (Milliken n.d.).

San Felipe Lake-Pajaro River connection

There has been substantial interest in understanding the hydrologic connection between San Felipe Lake and the Pajaro River before the construction of Millers Canal in 1874. Fortunately, the general nature of the connection between the lake and the river, as well as a number of specific characteristics, is fairly well-documented by historical data. Geographer Broek summarized this diffuse drainage system and the adjacent constructed drainage in 1932: "the Millers Canal which, in place of the shallow winding beds which is the beginning of the Pajaro River, now affords an adequate outlet for the San Felipe Lake."

In particular, two mid 19th-century surveys described the area (see fig. 5.5). Sherman Day, Deputy Surveyor in the U.S. Surveyor General's Office, crossed the area in late June 1854, on the north-south course of a sectional boundary in the Public Land Survey. Four years and three months later, Santa Clara County surveyor Charles Healy established the Santa Clara County/San Benito County (Monterey County at the time) line. This latter survey clearly attempted to follow the hydrological connection between the Pajaro River and San Felipe Lake. A number of maps and other sources provide additional evidence.

These sources describe a series of seasonal and perennial wetland habitats that connected San Felipe Lake to the more well-defined reach of the Pajaro River which began at the Llagas Creek confluence. Morphology can be considered to have had the following sequence, from the lake to the river.

Water overflowed San Felipe Lake into a well-defined freshwater slough. The term "slough" is probably indicative of relatively broad, shallow channel geometry and wetland margins. Day's report of surface water (and use of the term "laguna") about 600 m (2,000 ft) downstream of the southwest margin of the lake in late June suggests perennial character at this end of the system. This slough is still substantially intact, apparently with largely original shape, for several thousand feet from the lake outlet. Day reported a width of about 30 m (100 ft), also similar to the present-day form.

The point at which this feature presently shifts from a sinuous to a straight alignment is very close to the location where Healy (1858a) reported that the "main slough from lake spreads out into swale." Artificial ditching was probably initiated at this point to confine flow where it naturally began to spread broadly.

There was also a secondary slough outlet from the lake noted by Healy (1858a,b), 100 m (330 ft) northwest of the main outlet. This location corresponds closely with the present-day opening to Millers Canal. It is not known exactly how the upper slough connected to the lower.

The morphology downstream was described repeatedly as a "swale" by Healy, in explicit distinction from the "sloughs." This term presumably refers to an extremely broad and shallow cross-section; he notes a swale 300 m (1,000 ft) wide at one point. Despite the diffuse shape, however, these features still are distinct in the field. Lying at the low point of the surrounding floodplain, these drainage swales were probably flooded for weeks or even months at a time in the winter. Healy's (1868) description of the area had him placing a post "in a broad island in shallow channel over which the water sheds and flows, from the lake San Felipe to the Pajaro River in the wet seasons."

"...a broad island in shallow channel over which the water sheds and flows, from the lake San Felipe to the Pajaro River in the wet seasons..."

— HEALY 1868

As the system turns south, the swales coalesced again into narrower, more well-defined sloughs. Heading upstream in this area (near the present day Frazier Lake Road crossing), Healy stated that "it is impossible to trace the main channel farther; the sloughs are from 30 to 80 links wide and branch out in every direction" (Healy 1868). Just downstream a "main slough" could be identified, but it was just 2 m (6 ft) deep and only 6-20 m (20-66 ft) wide (Healy 1858a). Upon reaching the confluence with Llagas Creek, Pajaro was finally considered a river, presumably because of the formative flow contributed by the Llagas Creek watershed. An early survey refers to this point as "the head of said [Pajaro] river" (Lewis 1850b). Even at this point, it is possible that the Pajaro River was still fairly shallow and broad, until finally transforming into a more substantial river south of the old Carnadero Creek confluence (near the current railroad crossing). This is suggested by the design of Millers Canal, which enters the Pajaro River just below the old Carnadero Creek confluence, indicating that this may have been the first point where water could reliably be drained into a defined channel.

Surveyor Sherman Day described this drainage as "the chain of sluggish ponds, connecting the San Felipe River [Pacheco Creek] with the Pajaro" (Day 1854). His survey line crossed one of these ponds and recorded it in detail, about 600 m (2,000 ft) west of the San Felipe Lake outlet. His notes record a "laguna" 34 m (110 ft) wide, bordered by "a salt marsh" at the "[e]dge of water on N. side."

"S. edge of laguna, here tending to W. This is one of the chain of sluggish ponds, connecting the San Felipe River [Pacheco Creek] with the Pajaro."

- DAY 1854

Day's observations were made on June 22, 1854, an average water year based upon San Francisco rainfall records (the only regional dataset available for that period). His use of the terms "laguna" and "ponds," as well as the extent of water in late June, suggests the presence of smaller perennial ponds and wetlands within the broader wet meadow/alkaline/seasonal wetland context. His description of a "chain" of similar features indicates that there were additional perennial freshwater ponds continuing downstream within the broad swale extending towards the Llagas/Pajaro confluence. Other than this laguna, we have no direct evidence for the amount and location of these features, but their historical presence is very probable. This is corroborated by Crespí, describing the mosaic of ponds, wetlands, and water courses that characterized the Bolsa in 1772:

> There is a positive maze of very large freshwater lakes with a great deal of swamp and bulrush patches in this hollow, and I know not how many large running streams... (Crespí [1772], in Milliken et al. 1993)

The diagrammatic feature shown by Thompson and West (1876) as a large triangle of marsh actually corresponds well to this picture (fig. 7.24). The shape coarsely matches the wet meadow area indicated by historical soils and containing the swales and sloughs described by Healy and Day. The sloughs shown along the upper boundary of the triangle generally match the alignment of Healy's swale. While the long portion of the triangle does not directly correspond to a drainage, it bounds the area with strongest wetland character (it may also be intended to represent Millers Canal, constructed just two years before).

There is some indication that the entire area connecting San Felipe Lake to the Pajaro River may have been referred to as Tequisquita Slough, implying that it was seen as a continuation of what is now known as Tequisquita Slough (and, by extension, San Felipe Lake) rather than as the uppermost part of the Pajaro River. John Gilroy (1861, in Gudde and Bright 1998) asserted that "this ditch [Tequisquita Slough] is now called the Pajaro." One map confirms this: the channel connecting San Felipe Lake to the Pajaro River is labeled "Tequesquite Slough dry in summer" (U.S. District Court, Northern District 1860; fig. 7.25).

The western Bolsa

The character of the upper Pajaro River was closely linked to the freshwater inputs from the surrounding floodplain and the aptly named Pajaro Lake. Font, traveling in March 1776, noted that the area around Pajaro River "is miry and when it rains heavily it is for the most part a lake" (Bolton and Font 1933). In severe flood years, this lake could cover the area from Gilroy to the north, Hollister to the south, Dunneville to the east and Sargent to the west:

> Mr. Tom Hawkins, when interviewed in the field, reported that in about 1910 it was possible to row a boat from Dunneville to Gilroy. (King and Hickman 1973)

> Everybody seems amazed to see rain in the middle of June, but the old Mexicans here inform us that in June of 1844, the whole country from Hollister to Gilroy was flooded with water through the heavy rains. This statement, which seems incredible, is confirmed by Mr. Julius Martin, an old American citizen of Gilroy, who came to California in 1842. (San Benito Advance 1875a)

When a road from Gilroy to Hollister was proposed in 1869, potentially to be routed by Old Gilroy, objections were raised due to the frequent flooding on the route:

> The water, or I might term it a moving lake, has been known to be between two and three miles wide, and from thee [sic] to ten feet deep on this proposed road. (Gilroy Advocate 1869a)

Broek described the area in the 1930s, emphasizing the absence of trees in the alkali meadows. His perspective of the "barren plain" may have been affected by the substantial drainage efforts and dewatering of the Bolsa by that time:

> The highly developed cultural landscape north of the tree-bordered Pajaro River finds a striking contrast in the barren plain to the south. The Valley has here expanded into a broad basin…into large tracts of salt grass pastureland. Far to the east of this grassy level, willow thickets indicate several shallow sloughs which drain into the San Felipe Lake, the principal one being Tequisquita Slough. The western portion of the Bolsa de San Felipe, as the Spanish name designates the barren central part of the plain, is practically treeless and entirely without water courses. (Broek 1932)

Author Bayard Taylor (1850) described the meadows around the Pajaro eighty years earlier (which he lyrically called "the Pajaro Plains"), giving a somewhat different perspective:

> The Pajaro Plains, around the head of the river, are finely watered, and under proper cultivation would produce splendid crops. From the ridge descending to the valley of San José we overlooked their broad expanse. The meadows were still green, and the belts of stately sycamore had not yet shed a leaf. I hailed the beautiful valley with pleasure, although its soil was more parched and arid than when I passed before, and the wild oats on the mountains rolled no longer in waves of gold. Their sides were brown and naked to desolation; the dead umber color of the

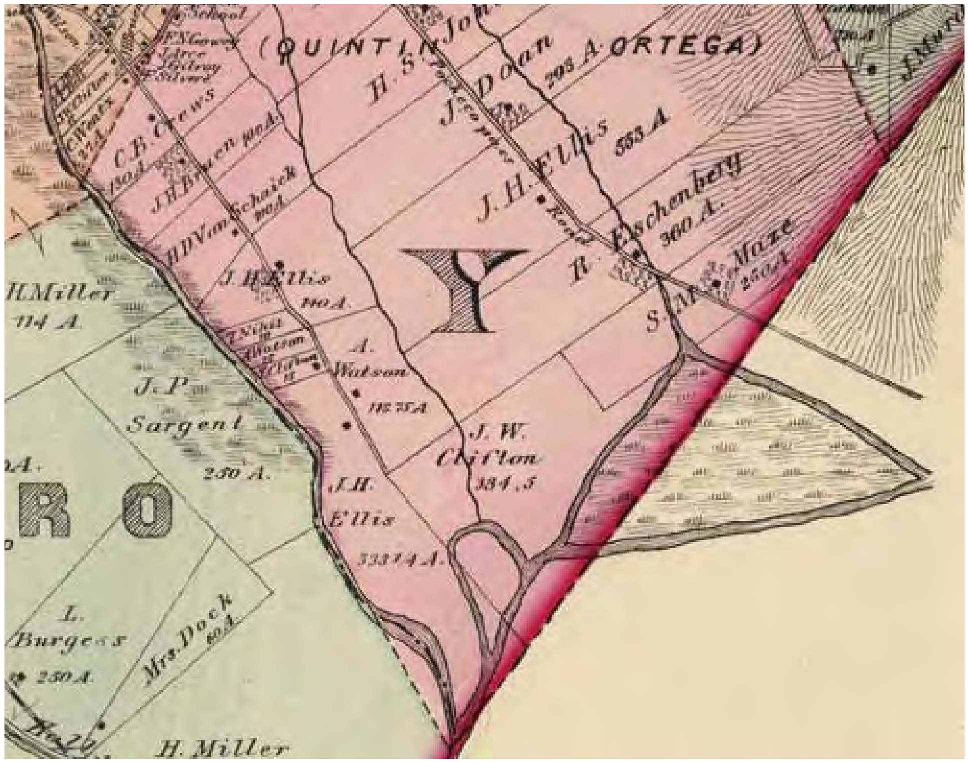


Figure 7.24. Here Thompson and West (1876) show the wetlands along lower Llagas Creek (upper left). The odd triangular array of channels surrounding marsh symbols on the right represents the drainage from San Felipe Lake to the Pajaro River. The lower channel may represent Millers Canal, completed just two years earlier. The upper channels suggest the arcing path of the natural drainage swale connecting the two systems. (Courtesy of the David Rumsey Map Collection)

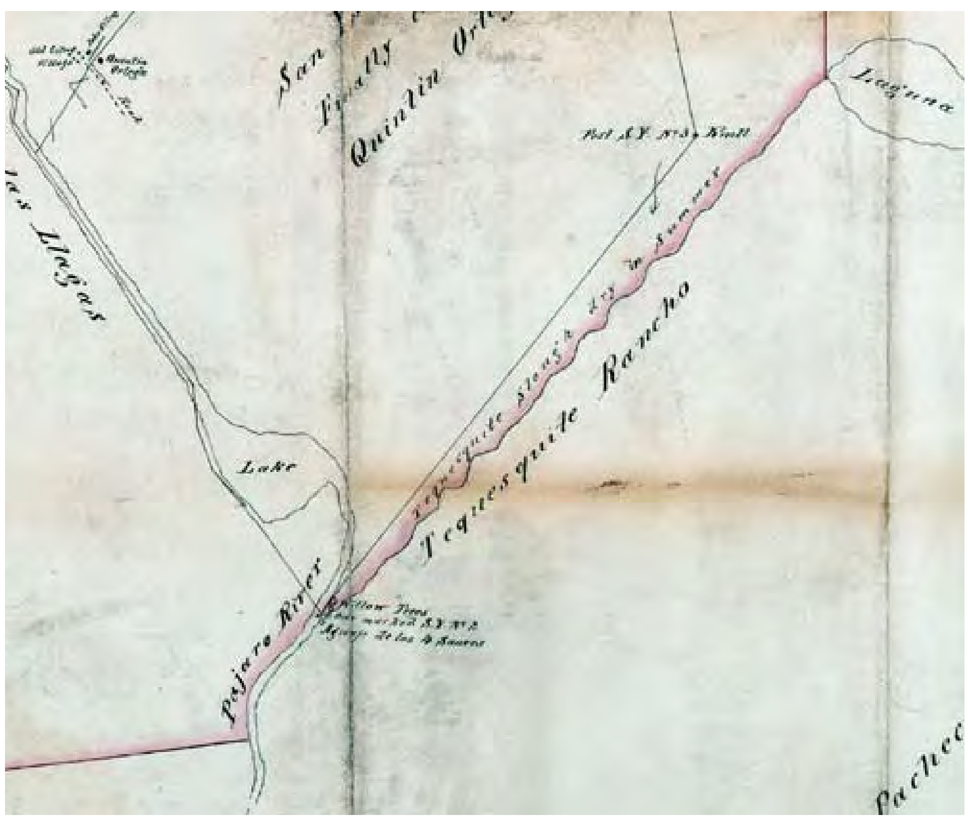


Figure 7.25. This map captures the historical relationship between San Felipe Lake ("Laguna") and the Llagas Creek-Pajaro Lake-Pajaro River system. The primary origin of the Pajaro River was clearly Llagas Creek and Pajaro Lake ("Lake"). San Felipe Lake did not overflow directly into a river channel, but into a slough that was "dry in summer." The drainage between San Felipe Lake and the upper Pajaro is here called Tequesquite Slough, which is either a naming mistake or else reflects that the feature was considered an extension of the slough of that name upstream. (U.S. District Court, Northern District 1860, courtesy of The Bancroft Library, UC Berkeley)

> landscape, towards sunset, was more cheerless than a mid-November storm. A traveler seeing California only at this season, would never be tempted to settle.
>
> As we journeyed down the valley, flocks of wild geese and brant, cleaving the air with their arrow-shaped lines, descended to their roost in the meadows. On their favorite grounds, near the head of Pajaro River, they congregated to the number of millions, hundreds of acres being in many places actually hidden under their dense ranks.

> *"...the Bolsa presents only a grass vegetation, mostly salt grasses..."*
>
> – BROEK 1932

The flat, poorly drained west Bolsa region, from Lomerías Muertas east to Tequisquita Slough, was defined by a predominance of alkaline soils and a near total lack of drainage. Broek (1932) called it "practically treeless and entirely without water courses"; Brewer, traveling in 1861, called it a "dead-level plain, tedious and monotonous" (Brewer [1930]1974).

The west Bolsa was largely comprised of thousands of acres of salt-affected grassland and seasonal marshland, with few water courses draining the area. These conditions were described by numerous historical sources and were the origin of the tequisquite - mineral deposits used, along with tallow, in the making of soap that led to many of the local place names (Llano de Tequisquita, Tequisquita Slough, Soap Lake). Surveys by Sherman Day affirm the alkaline, salt marsh characteristics with terms such as "salt grass," "salty plain," "salt swale," "samphire grass," and "miserable salt land" (Day 1854). One survey described the conditions of alkaline affected soils prevalent in the Bolsa as "stiff clay, mixed with much alkali inclined to be wet in winter and to bake in summer. Bears a poor grass" (Day 1854). The diary of Francisco Palou, recording the Anza expedition of 1774, referred to "patches of bad and salty land without grass or trees" when they crossed the Bolsa (Bolton et al. 1930, Brown 2005). Surface accumulations of salts and halophytic plants are still found commonly in the area.

The zone of alkali effects began in the vicinity of Lovers Lane and continued westward to the San Felipe Lake-Pajaro River drainage, affecting vast areas of seasonally wet grassland. Cosby and Watson (1927b) identify a narrow (~500 m/1,650 ft) band of soils with lesser, yet significant, alkali conditions at the eastern margin of alkali meadow, in the vicinity of Lovers Lane, west of Tequisquita Slough, and northeast of San Felipe Lake. These slightly better-drained areas were marginal to the major portion of the Bolsa, which was strongly impacted by residual salts (Cosby and Watson 1927b). The ecotone between alkali meadow and slightly higher ground even served to define the Santa Clara County boundary near Pacheco Pass Road. In the absence of other defining features, Healy's line runs "along where the weeds and mustard of the plain mingle with the salt grass and samphire [pickleweed] of the marsh" (Healy 1858a).

SAN FELIPE LAKE AND THE EASTERN BOLSA

If the western Bolsa was characterized by treeless alkaline plains, the eastern Bolsa was dominated by willows, wetlands, and watercourses. Water - artesian groundwater, the spreading of Pacheco Creek, Tequisquita Slough, and the alluvial deposits and wetland areas created by this water – defines the area.

Historical habitat patterns reflect the combination of two independent physical processes: physical gradients (soil particle size, depth to groundwater) associated with the distal end of alluvial fans plus the restricted drainage caused by the Calaveras fault (sag ponds).

Lovers Lane roughly marks the eastern margin of the great Soap Lake wetland complex, which encompassed an array of distinct wetland habitat types. East of San Felipe Road, grasslands and oak savanna followed Pacheco Creek as its coarser alluvial deposits dissipated into the Bolsa.

Tequisquita Slough and other sloughs

The two most detailed early maps of San Felipe Lake (from 1858 and 1880) clearly show the open water area of San Felipe Lake dividing into several wide sloughs extending east and southeast. While the earlier map shows these features somewhat diagrammatically, the sloughs of the 1880 map show some correspondence to later aerial imagery. (We mapped their shape and location based upon a combination of these maps and 1939/2005 aerial imagery.) The sloughs at the northeastern margin of the lake remained particularly intact. We were able to find evidence connecting almost all of the lake-margin sloughs to sloughs entering the wetland complex from the south and east.

There were at least three major sets of sloughs that entered the San Felipe wetlands complex, all from the south and east. First, Pacheco Creek spread into three smaller channels (see fig. 7.29). Second, a significant channel appears to have initiated on the valley floor south of Pacheco Creek near Dunneville. This channel may have been a former Pacheco Creek channel during recent geologic times. In the historical era, it likely intercepted groundwater and surface runoff. Last, Tequisquita Slough connected to Santa Ana Creek and Arroyo de las Víboras and approached San Felipe Lake from the south.

Some evidence of historical sloughs is still visible in 1939 aerial imagery as well as in contemporary aerial photography. These residual features often correspond closely to the alignments indicated by historical maps, helping confirm the historical data. For example, sloughs entering the Tequisquita marshes from the east apparently served as the property boundary between two farms (McCray 1907) and now persist in the form of a narrow channel following the same alignment (fig. 7.26).

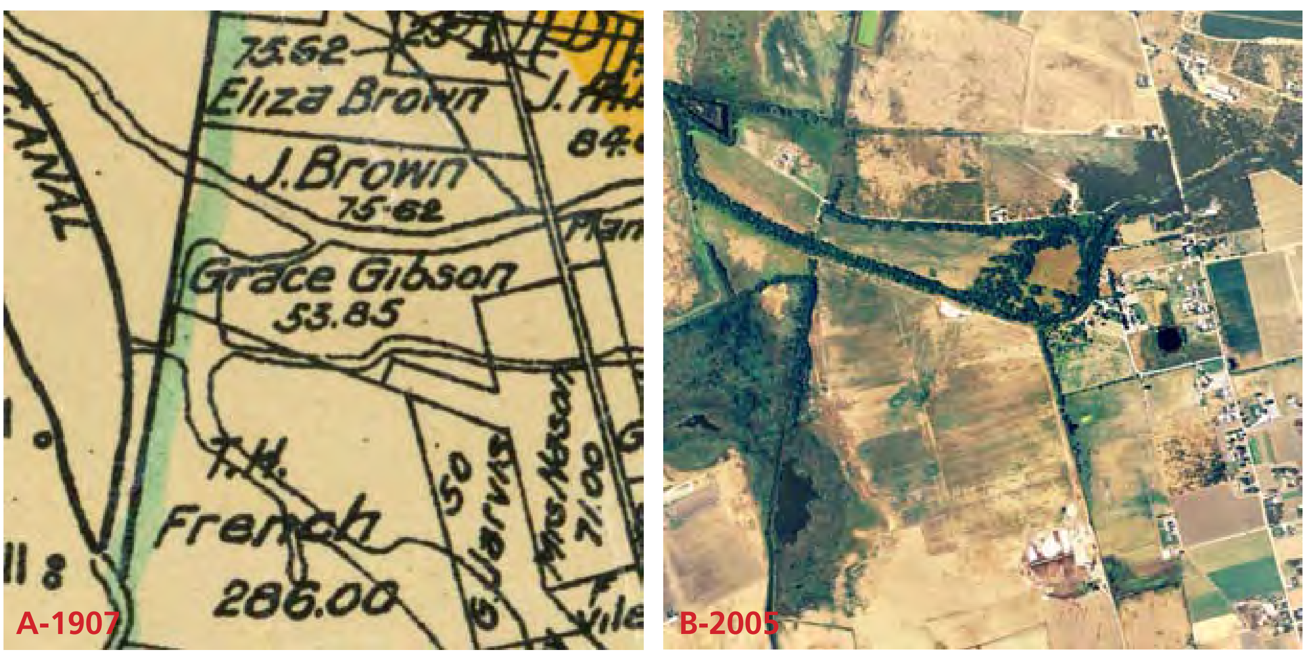


Figure 7.26. Remnants of complex slough patterns from 1907 (A) still function in 2005 (B). The boundary between Brown and Gibson appears to have been a slough; that boundary is still visible today. (A: McCray 1907, courtesy of the Earth Sciences and Map Library, UC Berkeley; B: USDA 2005, courtesy of NAIP)

Freshwater wetlands and the eastern lake shore

Unlike the steeper western shore, the eastern margin of San Felipe Lake was defined by extensive perennial freshwater wetland complexes. Explorer Pedro Fages, traveling northwest along the edge of the hills northeast of San Felipe Lake in November 1770, noted “many reed patches crossed by numerous bear trails. At the place where they end there was a very large pool [San Felipe Lake], and at the head of this a village of heathen...” (Fages and Bolton 1911). Crespí came upon the area on March 23, 1772, approaching from the southeast. He captured the contrast of the flat, treeless plain with the densely forested lower reaches of streams, likely Tequisquita Slough and Pacheco Creek. Open water was more prominent in the spring than during Fages' late fall observations.

> ...we entered another broad and spacious one [plain; Santa Clara Valley], about four or more leagues wide; its longest dimension is from northwest to southeast, but its termination is not known. The land is very good, with abundant pasturage, and it has innumerable large lagoons of fresh water and three our four villages of heathen, who, by means of rafts, catch a great deal of fish in the lagoons...The valley has several arroyos of good running water, whose beds are well grown with trees–cottonwoods, alders, and willows–but on the plains not a tree is to be seen, though they are all covered with grass. (Crespí and Bolton 1927)

Historically, San Felipe Lake was often considered to include these surrounding wetlands. The Healy (1858a) survey defining the county line and the accompanying map (Healy 1858b) clearly make this point. A series of survey points refer to the “bank of lake” although the accompanying map shows the boundary following the margin of freshwater wetlands, with the “deep water” portion of the lake farther out (see fig. 5.10).

It made sense to consider these areas practically part of San Felipe Lake since they could flood dramatically during the wet season. Early landscape photographs show large areas flooded north and east of the lake, extending nearly to the hills (fig. 7.27).

> *“The land is very good, with abundant pasturage, and it has innumerable large lagoons of fresh water...”*
>
> – CRESPÍ, MARCH 1772

Perennial freshwater wetlands can nevertheless be distinguished from the open waters of the lake and more seasonal wetlands. The best evidence for the eastward extent of the perennial freshwater marsh bordering the lake comes from Herrmann's (1872) survey in which he sketches a boundary of “tule” to within about 1,000 m (3,300 ft) west of Lovers Lane. This extent corresponds generally with dark mottled soil patterns indicative of wetlands in the 1939 aerial photography. It also corresponds with the eastern boundary of Francisco Perez Pacheco's Ausaymas land grant, which apparently was defined by the margin of San Felipe Lake (U.S. District Court, Southern District [184-?] e). Other diseños (U.S. District Court, Southern District [184-?]a,e) also show the freshwater marsh on the eastern margin of San Felipe Lake parallel with the elongate willow grove to the north, corresponding with this extent (fig 7.28). The northern extent of freshwater marsh marginal to San Felipe Lake is suggested by Healy's survey fieldnotes, which report his position “3 ch left of tules [~60 m/200 ft]” along the county line.

Freshwater marsh

Between Lovers Lane and San Felipe Lake, wetland types followed a general hydrologic gradient of increasing water depth and inundation towards the lake. These radiating zones of wetland types were punctuated by springs and seeps which created an array of perennial ponds and wetlands, both associated with the Calaveras fault and scattered through the Soap Lake area. Healy (1858a,b) captures this pattern in describing the

Figure 7.27. Three views of the Soap Lake floodplain from the northwest margin of San Felipe Lake. A and B were taken when the lake was in flood; submerged trees are evident. The lower image shows more average conditions, in 1894. While the image is somewhat indistinct, the white areas behind the far shore may be the sloughs and wetlands shown in 19th-century maps (see fig. 5.10). Parts of the lake's east (far) shore that are wooded today have no trees in the photograph, contributing to a picture of wetter conditions historically. (A (Unknown ca. 1900d) and B (Unknown ca. 1900e): courtesy of the San Benito County Historical Society; C: Unknown 1894b, courtesy of the Gilroy Museum)

Figure 7.28. Riparian trees along Pacheco Creek give way to a willow grove (labeled "Sausal" in the inset), freshwater marsh, and open water, as the creek flows from right to left into the San Felipe Lake wetlands. Different versions of the same land grant map often show additional symbology or annotation that can help with interpretation. (U.S. District Court, Southern District [184-?]e and U.S. District Court, Southern District [184-?]d (inset), courtesy of The Bancroft Library, UC Berkeley)

general area as "tules and salt grass" (see fig. 5.10). Smaller freshwater marshes are revealed by a variety of sources, including features crossed by GLO survey lines and wetland symbols illustrated around "springs" in McCray (1907). It is likely that many more small ponds and marshes were scattered through the area than we actually show. Several larger freshwater marshes are well-documented, however (see Chapter 5).

There was a large area of valley freshwater marsh just west of Lovers Lane at Tequisquita Slough. Historically, Tequisquita Slough spread into this marshland, entering from the south. The land grant boundary between ranchos Llano de Tequisquita and Ausaymas y San Felipe, which follows the slough to this point, leaves the slough to follow a straight line northeast to the hills. Like the "mouths of Pacheco Creek" (see fig. 7.29), this point where the well-defined slough spread into more dispersed drainage system was a significant, identifiable landmark.

An extension of this wetland complex continued east across Lovers Lane to San Felipe Road, south of Pacheco Creek, occupying an interfluve of bottomland clay soils between fingers of the Pacheco Creek fan. Both this marsh and a larger marsh to the west were shown by Healy (1858b) and by the USGS (1921). Healy shows springs associated with the eastern marsh. Both features correspond at least in part to contemporary, albeit smaller, wetland features.

A large freshwater marsh is also indicated to the south by Terrell (1858), crossing Shore Road on the western side of Tequisquita Slough. A smaller slough ran through this area and was referred to as the "Tequisquita Slough overflow" as late as 1949. This area may be the "swamp" that defined one of the borders of the Rancho Bolsa de San Felipe (Sanchez 1852).

Willow groves

Large willow groves were also found just west of Lovers Lane, well-documented by Healy (1858b) and affirmed by Cosby and Watson ("water grasses and willows"; 1927b). Healy also shows sloughs disappearing into willow swamps to the south and west; one diseño similarly shows a "Sausal" on the west side of "Sanjon del Tequisquite" where it enters the San Felipe Lake wetlands (U.S. District Court, Southern District [184-?]f). Elongate willow groves also followed the county line along the northern margin of the lake near Pacheco Pass Road. These were documented by Healy (1858b and 1880a). Portions of these remain today (see figs. 5.10 and 5.11).

One land grant map, a sketch of the Rancho Ausaymas, shows several of these features in relation to the grant boundary, confirming their presence and relative position in the 1840s (U.S. District Court, Southern District [184-?] d). It shows a "Sausal" north of San Felipe (Pacheco) Creek where it enters the San Felipe Lake marshlands, and a thinner stand of trees along the lake margin to the west. The diseños of the Rancho Llano del Tequisquita also show a distinctive woodland on Pacheco Creek's north bank as it enters the "Laguna" (U.S. District Court, Southern District [184-?]a,b; U.S. District Court, Northern District [184-?]b). A number of the groves appear to be closely associated with the margin of alkali soils.

Significant remnant stands occupy their precise historical positions on the northern margin of San Felipe Lake. The elongate willow grove sandwiched between Highway 152 and the perennial lake margin appears to have regenerated during the 20th century. While the feature was documented in both 1858 (Healy 1858b) and 1880 (Healy 1880a), two landscape photographs taken around the turn of the 20th century do not show any significant willow stands at that location (see fig. 7.27). A small stand is visible in 1939. Since then the grove has expanded substantially and resembles the historical stand.

The giant willow grove at the mouth of Pacheco Creek has been essentially completely removed and converted to a residential and agricultural landscape. However, willow trees are currently found frequently along and around Lovers Lane (see fig. 5.14) within the extent of the historical grove, suggesting the historical habitat is still viable. Willows are not a common streetside or yard tree in the surrounding areas (unless associated with drainages). For example, none are observed along San Felipe Road, the next road to the east, which was outside of the historical extent of willow groves and artesian groundwater.

PACHECO CREEK

Pacheco Creek historically underwent a series of transitions over its course, from a broad, braided, gravelly morphology above its confluence with Carmen Creek to a single thread channel in lower Pacheco Valley before dissipating into multiple channels on its alluvial fan in the eastern Bolsa (east of Lovers Lane). Originally called San Felipe Creek, Pacheco Creek was a major hydrologic input to San Felipe Lake, which Day (1854) called "the laguna of San Felipe Creek."

Spreading of Pacheco Creek

At the intersection with San Felipe Road, Pacheco Creek dissipated into several distributaries or sloughs (Healy 1858a,b) as the stream gradient flattened. This transition point in the system served as a significant landmark for the county line – the point at which the Santa Clara County line begins its course due east-west – making contemporary geolocation highly accurate. Surveys by Healy (1858b and 1880a) each explicitly show Pacheco Creek spreading out at San Felipe Road (fig. 7.29). Healy's fieldnotes reiterate the pattern, referring to "the junction of the mouths of San Felipe" and the point "near where one of the many channels or mouths of the San Felipe Creek spreads out into the lake" (Healy 1868). Discussion of the Santa Clara County boundary refers to the decision "to run a straight line… to the point where the San Felipe Creek was found to be an entire stream" (i.e., where the single channel spread into many). The use of this feature to define an important political boundary indicates that it was well recognized and identifiable in the field, and expected to be fairly persistent.

> *Ditches have also been constructed to conduct the flood waters of the Tequisquita Slough to the lake. These measures, however, have never been sufficient to allow a higher grade of land utilization in the region and, on the other hand, there has been no inducement to construct elaborate works because of the low value of the land. Thus, Pacheco Creek still has no direct connection with the Tequisquita Slough, but terminates in the shallow channels which in turn have outlet only through a little ditch leading to an extensive swamp in the shallow depression northwest of Pacheco Corners. Only in winter do the floods from this swamp find an outlet into the Tequisquita Slough.*
>
> — BROEK 1932

Healy (1858a) recorded three large sycamores as bearing trees (1-2 m/3-5 ft in diameter) at this location, also indicating a persistent channel location. West of San Felipe Road, an array of shallow, low gradient channels distributed water across thousands of acres.

The area west of the spreading of Pacheco Creek was highly susceptible to flooding, as one family living along Pacheco Creek between San Felipe Road and Lovers Lane around 1900 found: "The John Warburtons lived...on the south side of Pacheco Creek. Every year, when the heavy rains came, the Warburtons were flooded out when the levy [sic] broke along the creek" (Williams 1968a).

In the 1940s San Benito County, Public Works engineers complained that the channel was naturally undersized for its flows:

> Pacheco Creek at this point has always been too narrow and choked with willows to carry flood crests, with the result that surrounding farm land has been flooded every few years. (Hanna 1948(?))

> This crossing [Lovers Lane] is near the outlet of Pacheco Creek into San Felipe Lake, and the creek is choked with willows and has adverse grade in places. (Hanna 1947)

These accounts describe a shallow, low gradient slough precisely at the location where it historically entered willow groves.

Pedro Fages, a Spanish explorer passing through the Bolsa and Pacheco Creek area in late November 1770, crossed what was likely the lower reach of Pacheco Creek at the eastern edge of the Bolsa on his way to find an inland route from the mission at Monterey to the San Francisco Bay (Milliken et al. 1993). He describes a "water-course thickly grown with alders, and having a very large pool of fresh water" (Fages and Bolton 1911).

The alluvial fan-wetland transition

> *"No description is adequate to cause a full realization of its tediousness"*
>
> — WILLIAM BREWER 1861, DESCRIBING THE BOLSA

From the east, Pacheco Creek's alluvial fan created a mile wide zone of well-drained soils slightly elevated above the surrounding lowlands. This naturally higher ground supported dryland habitats such as grassland and oak savanna, and defined the eastward margin of the San Felipe Lake wetlands. Geologist William Brewer described traveling from San Juan Bautista across this transition between the San Felipe lowlands and Pacheco Creek uplands in 1861:

> First a ride of eighteen miles across the dead-level plain, tedious and monotonous...To one who has never tried riding on a level plain, no description is adequate to cause a full realization of its tediousness...but at last a belt of scattered oaks is entered. Then we strike up a canyon, on the Pacheco Pass... (Brewer [1930]1974)

By the early 20th century, orchards covered these prime agricultural lands. As far west as Dunneville, "Yolo silt loam and associated soils are extensively planted to orchards of prunes and other fruits, including peaches and pears" (Cosby and Watson 1927b). Yolo silt loam was considered "the most desirable soil in the Hollister area." In 1910, unimproved orchard land was valued at as much as $150 an acre (compared to $50-$80 an acre for grain land; Wells ca. 1910). Mature prune and apricot orchards were valued as high as $2,500 an acre in 1923 (Cosby and Watson 1927b).

Artesian wells and the San Felipe district

The point at which Pacheco Creek spread into multiple sloughs also closely marks the beginning of Soap Lake's artesian zone. In his study of groundwater conditions in the Santa Clara Valley, Clark (1924) mapped this boundary based on artesian or "flowing" wells existing at that time and local recollection of wells that were no longer artesian. The eastern edge of pre-modification

Figure 7.29. This portion of Healy's 1858 map of the Santa Clara County line shows the spreading of San Felipe (Pacheco) Creek into the San Felipe Lake marshlands. (The edge of "Lake San Felipe" is shown at upper left.) Healy ran the boundary, drawn in red, around the edge of the "Tules and salt grass" and then made a straight line to the point at which the creek branched, before heading due east (on the right hand side of the map). The map also shows a spring-fed marsh (lower right) and willow groves, indicated by tree symbols and the phrase "dense thicket." (Healy 1858b, courtesy of the San Benito County Recorder's Office)

artesian waters crosses through Pacheco Creek's point of distribution and generally follows San Felipe Road, a cultural landmark reflecting several significant landscape boundaries or transitions.

At San Felipe Road, the Pacheco Creek alluvial fan also spread into broad fingers (at a larger scale than the stream distributaries) as it graded into the clay-rich soils of the lowland. In between the fingers, the wetlands and alkali conditions common to the west interwove with the higher and drier fans soils, such as the springs and freshwater marsh shown by Healy (1858b) and remnant in the USGS quad (1921).

Between San Felipe Road, Lovers Lane, Pacheco Pass Road, and Shore Road, the orchards and oaks of the well-drained loams of the east transitioned to the salt-affected, wetland soils of the west. In this area the ecotone was especially ideal for agriculture and early American settlement: high-quality, well-drained soils supplied with artesian water. Yolo silt loams transitioned into Yolo fine sandy loams as only finer sediments were carried westward by diminishing stream energy. Cosby and Watson (1927b) captured this gradient, noting that while the "eastern portion" "represents an alluvial fan" at an elevation of a few feet above the valley plain, "the western portion is low and poorly drained."

This area, known as the San Felipe district of the Soap Lake area, was the "garden spot of San Benito county" (Hollister Free Lance 1886b; see Chapter 3). It was renowned for its lush appearance, its thriving orchards and dairying businesses (and later, for vegetable and seed crops).

> *"San Felipe is a conspicuous spot, because it is evergreen, and during the dry seasons presents a marked and pleasing contrast to the brown and dusty fields and hills which one sees everywhere else... It is superfluous to speak of the fertility of this soil."*
>
> – HARRISON CA. 1888

But by the west side of Lovers Lane, these same soils were affected by "injurious quantities of alkali, and support[ed] a growth of water grasses and willows" (Cosby and Watson1927b).

As a result of intensive agricultural use of this area groundwater levels plummeted in the early part of the 20th century. By 1910, the "artesian wells which flowed all year" (Anderson n.d.) around San Felipe were beginning to run dry: "some of the wells do not always flow, and the use of pumps is general" (Wells ca. 1910). The artesian boundary moved west from approximately San Felipe Road to Lovers Lane by the 1920s (likely partially as a result of extensive water use for alfalfa cultivation for dairy cattle), as the near surface groundwater was rapidly depleted by local irrigation and by drainage.

Wetlands along Pacheco Creek

Further up Pacheco Creek, near its broad U-turn into Pacheco Valley, a series of ponds, channels, and wet meadows formed near the base of the Diablo Range hills on the north and west, starting in the vicinity of the Highway 156 crossing. Extending for several kilometers downslope, this feature is revealed by a number of diverse sources including an elongate strip of poorly drained Dublin silty clay loam soils shown by Cosby and Watson (1927a,b), and remnant channels visible in 1939 aerial photography and historical maps. This feature had significance in the Mexican era, serving as a watering hole for cattle ranching (fig. 7.30). Healy (1865) referred to one of the ponds with a particularly distinct crescent shape as "Laguna," and a San Benito County survey in preparation for building the Pacheco Pass Road referred to a remnant "pond" around 1924 (California Highway Commission(?) ca. 1924). This parallel drainage to Pacheco Creek served runoff from the hills that was unable to enter Pacheco Creek because of its large natural levee, creating a continuous low area between the hills and river.

Figure 7.30. This circa late-1840s map shows a series of wetland-associated features between Pacheco Creek ("San Felipe") and the hills as the creek turns up into Pacheco Valley. An elongate poza (pool or lake) is shown, as well as large areas suitable for watering cattle (labeled "abrevadero"). (U.S. District Court, Southern District [184-?]d, courtesy of The Bancroft Library, UC Berkeley)

Single channel reach of Pacheco Creek

West of San Felipe Road, up through the valley until just south of the Carmen Creek confluence, Pacheco Creek underwent an abrupt transition. What downstream was a shallow, meandering, spreading stream became a single thread channel, narrow and fairly deep.

Herrmann (1872) records an average channel width of only 1.00 chain (20 m/66 ft) in this reach, and notes "banks steep." This is corroborated by the 1920s soil survey report for the region, which notes that below the Carmen Creek confluence, the Yolo silt loam covering the valley floor is "about 10 feet above the bed of the stream" (Cosby and Watson 1927a).

Though Pacheco Creek historically spread into several shallow, poorly defined channels west of San Felipe Road (Healy 1858a,b), by the early 1900s, the channel was fairly deep as it entered the Bolsa. Surveys, photographs, and descriptions of Pacheco Creek around San Felipe Road and Highway 156 from the early 1900s portray a wide, deep channel with ample willows and gravel bars (fig 7.31). While the creek channel alone was approximately 40 m (120 ft) wide at this point (Unknown 1924), the bank-to-bank width was much larger, with wide, gravelly bars populated with willow groves and the occasional pond.

The creek was also quite deep at this point. A circa 1920 cross-section of the creek at Highway 156 shows that the channel was approximately 6-9 m (20-28 ft) deep (California Highway Commission ca. 1924a). This is corroborated by an account from 1914 of a driver falling over the bank of Pacheco Creek at bridgeless San Felipe Road:

> at the point where the bridge had formerly been there existed on each side of the creek...a sheer drop of about twenty-five feet from the surface of the roadway to the bed of the creek... (Langdon 1920)

Later photographs of Pacheco Creek at San Felipe Road and Highway 156 also confirm this, showing bridges at both crossings wet above the level of the riparian vegetation (USACE 1973). This would support the 1920s maps showing extensive willow bars slightly above the level of the creek, with the banks high, about 6-9 m (20-30 ft), above the channel.

> *"There were two swimming holes; one down stream from the footbridge across the creek – this one for the boys. 'I can assure you that no boy would be caught dead in a bathing suit in that swimming hole,' Charlie said, then added that he had no idea of what went on at the girls' swimming hole up stream."*
>
> — ALTA WILLIAMS AND CHARLIE TURNER, HOLLISTER FREE LANCE 1968

There is also evidence for persistent summer pools in this reach of Pacheco Creek. There was apparently a notable pool in the vicinity of the Highway 156 crossing, where Pacheco lived, and there were popular swimming holes in the creek (one each for boys and girls) in the San Felipe area. One area resident recollects that "Pacheco's Indians lived down along the creek near the hill. There were lots of houses for the workers. There was a big pool in the creek. Mrs. Solarzano's family lived very near this pool" (Milliken n.d.).

Braided reach of Pacheco Creek

Above its confluence with Carmen Creek and below its split into north and south forks, Pacheco Creek was a broad, braided stream. The creek sometimes occupied nearly the entire valley floor with its multiple channels and broad, gravelly bars populated by sycamores and valley oaks (fig. 7.33).

One map (Winn 1915) shows the abruptness of Pacheco Creek's transition from a wider system with a narrow main channel to a single, narrow channel (see fig. 4.28).

When Santa Clara County surveyor A.T. Herrmann surveyed Pacheco Pass Road in 1872, he also recorded vegetation and creek characteristics in the valley (fig. 7.32). Herrmann noted that in many places above Carmen Creek, the stream bed dominated nearly the entire valley floor. At the upper reaches of his survey, about a mile south of the Cedar Creek confluence, Herrmann shows the creek occupying the whole valley floor, noting that the creek bed was "gravel" and "only about 10.00 [chains] [200 m/660 ft] fr base to base" (Herrmann 1872). Slightly further downstream, creek widths are recorded between 3-6 chains (about 60-120 m/200-400 ft). The creek is "very irregular, wide and washed creek bottom covers almost all ground up to base of hills" (Herrmann 1872).

Additional evidence supports this interpretation of upper Pacheco Creek. The 1927 soil survey depicts upvalley riverwash deposits indicative of a braided, multi-thread system. John Muir ([1872]1974) captured the array of habitats along the intermittent, gravelly stream as he followed the creek to Pacheco Pass in 1868:

> Through a considerable portion of the pass the road bends and mazes along the groves of a stream, or down in its pebbly bed, leading one now deep in the shadows of dogwoods and alders, then out in the light, through dry chaparral, overgreen carex meadows banked with violets and ferns, and dry, plantless flood-beds of gravel and sand.

Sherman Day crossed the creek in 1854, near where Herrmann noted a "very irregular" channel 18 years later. He noted a series branching channels, one "50 links [10 m/33 ft] wide" (Day 1854). Between that channel and another section of the channel to the north ("in channel again," Day notes), he records a "grassy bar with large sycamores," possibly the same bar shown on the soils map in this location. After a substantial distance – another 90 m (300 ft) - he recorded another

Figure 7.31. Map of bridge site at Pacheco Creek, ca. 1920. Willows populated wide, gravelly bars along Pacheco Creek, and a small pond is shown to the right. (California Highway Commission ca. 1924b, courtesy of San Benito County Public Works)

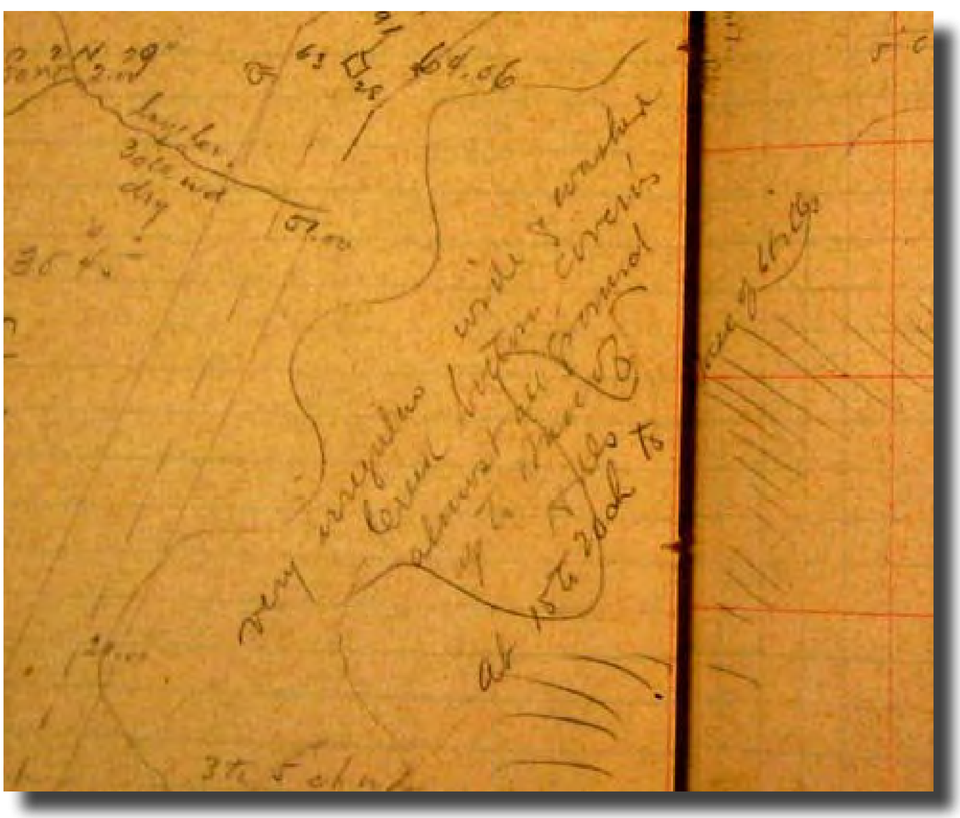
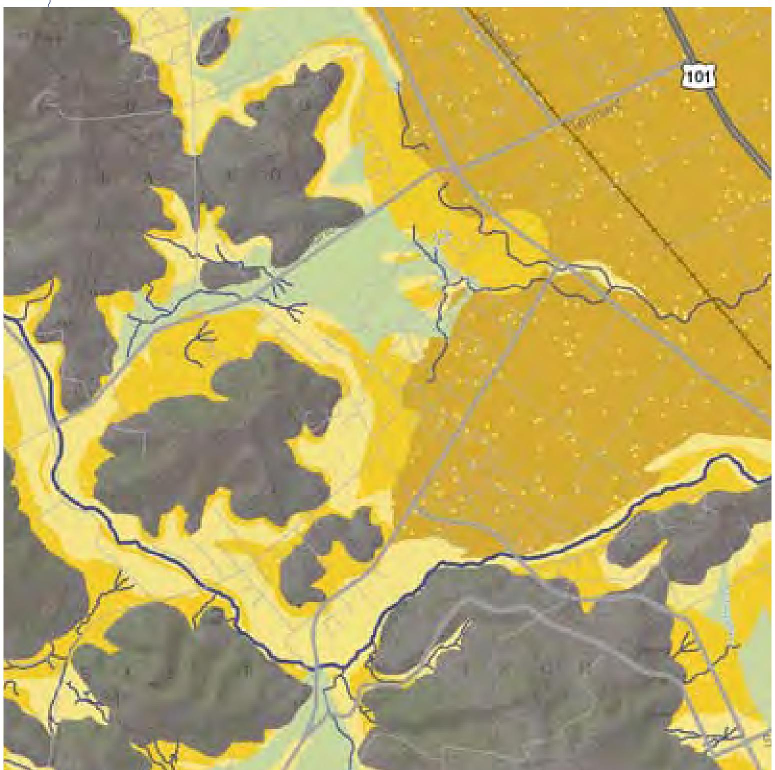


Figure 7.32. A.T. Herrmann, conducting a survey of Pacheco Pass Road in 1872, sketched upper Pacheco Creek (above Carmen Creek), and described it as: "very irregular wide and washed level bottom covers almost all ground up to base of hills." (Herrmann 1872, courtesy of the Office of the Santa Clara County Surveyor)

shallow channel: "Bank 2 feet high...Cross a bottom of rich soil through tall grass" (Day 1854). This early depiction of a series of shallow channels comprising a wide system matches Herrmann's depiction of the creek at this spot.

Figure 7.33. Pacheco Creek at Bell's Station, ca. 1910 (A) and rephotograph, 2008 (B). Individual sycamore trees can be seen on the creek, which runs along the base of Lovers Leap (the prominent peak at upper right). (A: Unknown ca. 1910b, courtesy of the Gilroy Museum)

8 SUMMARY OF FINDINGS



Above. Habitat map detail southwest of Morgan Hill.

Below. Valley oaks in contemporary Morgan Hill.

SUMMARY OF FINDINGS

This chapter provides a brief summary of some of the technical findings and associated management implications of the South Santa Clara Valley Historical Ecology Study.

LANDSCAPE LEVEL

The native South Valley landscape supported a diverse array of habitats, from dense valley oak woodlands in the north to repeating wetland mosaics in the southern part of the study area. The valley was almost evenly divided between grassland, oak savanna/woodland, and wetlands (including seasonal and perennial wetlands). Native habitats have declined dramatically (Table 8.1).

Historical habitat distribution was heterogeneous and can be largely explained by identifiable physical characteristics. Factors such as topography, soils, and hydrology are still likely to affect restoration potential. Consideration of historical habitat controls should improve the likelihood of restoration success.

Some of the native habitats and species that have experienced greatest local decline – such as sycamore alluvial woodland, lesser nighthawk, and least Bell's vireo – are at the northern margin of their historical range. Given anticipated climate changes and associated shifts in species range, these may be of greater local conservation importance in the future.

STREAMS AND RIPARIAN HABITATS

Prior to Euro-American settlement, the South Valley drainage network was much more discontinuous and diffuse. Streams commonly did not maintain defined channels across the entire valley floor. Instead, they sank into their alluvial fans and recharged groundwater, or spread into wetlands. Many channels were relatively shallow and prone to flooding. Sloughs and swales were common.

The drainage network has been expanded to drain the valley floor. Over 40% of the contemporary channel network was artificially constructed using new alignments.

Table 8.1. Historical extent of major south Santa Clara Valley habitat types. Where contemporary comparisons are available (Jones and Stokes 2006, USFWS 2007), the percent change (decline) is calculated.

Habitat Type	Historical Area	Current Area	% Decline
Freshwater Marsh	672 ha	66 ha	90%
Alkali Meadow	3,700 ha		
Wet Meadow	3,700 ha		
Willow Grove	831 ha	37 ha	62%
Oak Savanna Woodland	9,000 ha	164 ha	98%
Grassland	8,500 ha	1,888 ha (Santa Clara County only; figure does not include grassland in San Benito County)	

Most of the valley floor stream reaches were historically intermittent. Extensive historical evidence confirms that long reaches of Uvas-Carnadero, Llagas, and Pacheco creeks were seasonally dry across the valley floor.

Some intermittent reaches had persistent pools fed by subsurface flow. Pools were valued as fishing and swimming holes from native times through the early 20th century.

There were limited perennial stream reaches on the valley floor. Perennial flow on major creeks appears to have extended some distance downstream from the canyon mouth and, in some cases, reappeared where the lower reaches of streams intercepted groundwater.

The Pajaro River had unique ecological and hydrogeomorphic characteristics. Located in the historical artesian zone, the upper Pajaro River (San Benito River to Llagas Creek) had perennial flow and a dense, mixed riparian forest canopy, in contrast to other major South Valley streams.

Braided stream morphology was common on the major South Valley creeks. These broad reaches were interspersed with narrower, single thread reaches. Corresponding riparian habitat patterns were observed.

Open riparian savannas and woodlands dominated by California sycamore characterized the braided stream channels of South Valley. These high energy habitats included riparian scrub, occasional other riparian trees, and broad, unvegetated gravel beds and bars. Sycamore patterns varied from occasional, widely spaced trees along narrower channels to larger woodland groves on broad bars and terraces.

Riparian forest typically extended downstream from the canyon mouth on major South Valley creeks. The spatial transition from riparian forest to open riparian canopy was quite abrupt.

As a result of reservoir construction and operation, there has been a general conversion of open riparian canopy habitat to more densely wooded environments. The total length of forested reaches on the valley floor has more than doubled, while savanna and woodland reaches have decreased substantially.

Stream corridors have also consistently been constricted by land use changes. While riparian corridors wider than 60m (200 ft) were historically prevalent on the Uvas-Carnadero, Llagas, Pacheco, and Pajaro (70% of their valley floor length), now 70% of their length is narrower than 60 m (200 ft).

The lower reaches of Uvas-Carnadero, Llagas, and Pacheco creeks had substantial wetland reaches, where they spread into broad mosaics of willow groves and freshwater marsh. These areas provided an array of functions, including flood peak attenuation, fine sediment storage, and habitat for a diverse array of plants and wildlife, including a number of special status species.

While sycamore riparian habitat has been altered on most stream reaches, a significant remnant still exists on Pacheco Creek. This habitat is a regionally significant example of Central Coast Sycamore Alluvial Woodland.

Management considerations

Stream restoration could potentially reestablish natural stream benches and associated sycamore riparian habitat as part of natural flood protection efforts. For example, large remnant sycamore trees still remain along Llagas Creek, and could potentially be reconnected to the channel through restoration. Without specific efforts, this major element of the local natural heritage will probably disappear. Stream benches with scattered sycamores could also be re-created.

The Pacheco Creek sycamore alluvial woodland should be considered for its conservation value. Further research is needed to evaluate whether its long term health that would be improved through the use of scouring flood flows, carefully timed moistening flows for seedling recruitment, grazing management, and/or other stewardship actions.

Natural flow regimes have been altered on streams with large reservoirs. There may be further opportunities to adjust the timing and size of managed releases for ecological and geomorphic benefits. Higher flow pulse releases could potentially benefit natural stream maintenance processes, sycamore regeneration, and native fish populations. Well-timed late spring/early summer releases could potentially benefit both steelhead smolt outmigration and sycamore seedling establishment.

Different aquatic and riparian conditions may be appropriate targets for different stream reaches. Stream reaches can be evaluated in the context of the overall upper Pajaro River watershed by scientists, engineers, and water managers for appropriate, achievable reach-specific targets. Otherwise, stream habitat objectives may be in conflict. For example, summer water releases intended to benefit steelhead may have negative effects on remaining sycamore woodlands. Comparing historical conditions and existing potential may help identify viable strategies to balance competing resource objectives.

WETLAND HABITATS

Prior to Euro-American drainage efforts, wetlands occupied about 9,000 ha (22,000 ac) in South Valley. Most of these (83%) were seasonal wetlands, including wet meadows and alkali meadows. There were also 700 to 800 ha (1,700-2,000 ac) of perennial valley freshwater marsh and of willow groves.

Wetlands occurred in distinct landscape positions. Perennial freshwater ponds and marshes were always associated with fine-grained, clay-rich soils. Willow groves consistently occupied the margin between these poorly drained soils and adjacent coarser materials. Willow groves also followed groundwater discharge, associated with the outer margin of artesian conditions. Similar positions can be identified today.

Wetlands have experienced dramatic changes in total extent and other spatial characteristics. When compared with contemporary maps, historical sources indicate that the area of valley freshwater marsh has decreased by 90%. Willow riparian forest has decreased by a lesser amount (~60%), but the edge-to-area ratio of the remaining, more linear habitat patches has increased by over 700% compared to the historical habitats.

Alkali meadows dominated the Bolsa. These now rare habitats were extensive along the southern side of the Santa Clara-San Benito County line. Perennial marshes – both freshwater and saline – and ponds were scattered throughout the alkali meadows. Except for willow groves on the margins, trees were rare or absent.

Most of the wetlands in the study area were associated with the Soap Lake floodplain, a broad natural basin that historically supported a diverse and extensive array of wetlands. Topographic position, poorly drained soils, persistent alkaline soil effects, and seasonal flooding continue to give the area relatively high potential for wetland restoration.

Some significant wetland remnants remain. San Felipe Lake retains some of its historical size and function (see below). Several of the smaller historical willow groves are still intact.

Small portions of historical wetlands have recently reestablished as groundwater levels have recovered and some areas have become less intensively managed. In particular, small willow groves and scattered individual willow trees can be seen within the extent of historical willow groves.

Mosaics of willow groves, freshwater marsh, perennial pond, and seasonal wetland provided an array of species support functions. Willow groves and freshwater marsh almost always co-occurred. Both habitats were always fully or partially bordered by seasonal wetlands. Perennial ponds were generally surrounded by freshwater marsh.

San Felipe Lake, an Audubon Important Bird Area, has decreased in size and depth, and the surrounding wetland mosaic has been reduced. This rare regional example of a natural perennial freshwater lake was a cultural and ecological centerpoint for hunting, fishing, and soap-making. While the lake retains 50-60% of its historical area, the freshwater marshlands bordering the lake have been almost completely eliminated (93%).

San Felipe Lake historically overflowed into a series of sloughs, swales, and wetlands that converged into the Pajaro River at the Llagas Creek confluence. This diffuse drainage system had no well-defined channel or riparian corridor but rather a chain of seasonal and perennial wetlands.

Management considerations

Historical wetland locations offer a number of sites that should be considered for conservation and stewardship. Significant remnants include San Felipe Lake and the nearby remnant willow groves. There is also significant potential for wetland restoration along Tequiquita Slough and lower Pacheco, Llagas, and Ulvas-Carnadero creeks.

The potential to restore wetland mosaics in the Soap Lake floodplain is regionally significant. A number of factors suggest that restoration is technically feasible. Restoration could potentially benefit numerous species, including an array of native songbirds, shorebirds and waterfowl, floodplain-associated fish, outmigrant juvenile steelhead, and amphibians.

Historical wetland mosaics present a template for wetland restoration design. Dynamic floodplain wetland mosaics – incorporating willow groves, freshwater marsh and pond, and wet/alkali meadows – are likely to be able to support multiple life history stages of numerous species within relatively small areas. Restoration strategies can recognize existing topographic, edaphic, and hydrologic gradients to reestablish these kinds of patterns.

OAK SAVANNA AND WOODLAND

Valley oak savannas and woodlands occupied much of southern Santa Clara Valley outside of the Soap Lake floodplain. These oak lands covered an estimated 9,000 ha (22,000 ac) and have declined by 98%. We estimate that there were 60,000 oak trees, of which about 1,000 remain.

Oaks occurred on the valley floor in a range of densities. Relatively open savanna with scattered trees was most common (5,700 ha/14,000 ac), corresponding to an average stand density of about three trees/ha and an estimated canopy cover of 12%. There were also much denser valley oak woodlands. We identified an estimated 3,300 ha (8,000 ac) of woodland, with an average of 13 trees/ha, and an estimated canopy cover of approximately 50%.

Valley oaks dominated the oak lands of South Valley. 84% of the oaks recorded to species level by mid 19th-century General Land Office surveyors were valley oaks. Black oak and live oak were minor components overall, but there are indications that they could be more dominant in certain places.

Valley oaks declined dramatically during late 19th century conversion of woodlands to orchards. While the presence of large oak trees conflicted directly with the development of densely planted orchards, the trees have posed less direct conflict with other local land uses, including grazing, hay and grain farming, and even residential development, where they have been valued for shade and aesthetic value.

There are just a few remaining historical oak groves. These provide the last remaining local examples of the habitat.

Management considerations

While the extent of valley oak lands has declined precipitously, there are many trees and a few groves that have been preserved to date. In addition to stewardship of remaining individual trees, these significant remnant groves may be worthy of conservation attention.

The historical spatial patterns of valley oak in South Valley suggest that reintegration of oak habitat within the contemporary landscape is possible. Within the context of an urban forestry plan, valley oaks could be strategically reintroduced (in medians, parks, yards, and along road and fence lines) to achieve densities similar to historical conditions.

Increasing the density of oaks may be important to allow successful oak reproduction and maintain a healthy population. Existing trees may be genetically isolated and thus have less ability to successfully adapt to changing conditions.

Valley oak restoration could benefit a number of native species whose ranges have been declining in South Valley, such as acorn woodpecker and Pacific pallid bat. Certain oak-associated species are largely precluded from the valley by the lack of oak trees.

Valley oak restoration can have a number of practical and aesthetic benefits. As shade trees, they are recognized for being attractive, deciduous, relatively fast-growing, and drought tolerant.

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APPENDIX 1: CLIMATE HISTORY

Intertwined with the history of land use and landscape modification is climate history. Under natural conditions, climate change causes long-term shifts in native habitat distribution and abundance. Shorter-term climatic variation can also influence native habitat patterns indirectly by affecting land use, as droughts instigate reliance on groundwater or the failure and abandonment of a crop, and extreme winter floods catalyze stream channelization.

For millennia, large numbers of people have populated California due, in no small measure, to its climate. By the 1850s, newspapers in the east were already following the ups and downs of climate in California and its effects on commerce, settlement, logging, agriculture, and transportation (e.g., Farmer's Cabinet 1850; Pittsfield Sun 1854). Since statehood in 1850, California's climate has remained relatively stable, with extremes in rainfall, temperature, and drought not typically exceeding prior regimes in terms of severity or duration. Yet within that recent stability, substantial variability has affected cultural and landscape patterns.

Climatic controls

Climate and weather patterns are driven by a combination of regional physiographic characteristics, local topography and land use, the interaction of maritime and continental air masses, and global climate patterns. As in the rest of California, these forces have created a relatively stable climatic regime for roughly the last 150 years.

A principal factor driving the climate is a high pressure area of the north Pacific Ocean. This pressure center guides storms well to the north in summer months, bringing little to no precipitation during that period. In winter months, the Pacific high moves south, allowing storms to move through California, completing the Mediterranean climatic pattern. Lying approximately 24 km (15 mil) inland from the Monterey Bay, much of south Santa Clara Valley is separated from the ocean by the Santa Cruz Mountains, resulting in a mix of continental and coastal type climates. These mountains deflect much of the prevailing westerly winds of the Pacific high, yielding generally warmer summers, colder winters, moderately higher daily and seasonal temperature ranges, and generally lower relative humidities compared with coastal areas. The region is also influenced by summer fog generated by the interaction of warmer Pacific air masses and the cool water of the nearshore upwelling zone.

Other factors affecting the region's climate are the Pacific Decadal Oscillation (PDO), El Niño (ENSO), and La Niña cycles. These are trends in sea surface temperatures that can significantly affect marine biological productivity and coastal region weather patterns. Twentieth century PDO "events" have tended to persist for 20 to 30 years, while typical ENSO events persist for 6 to 18 months (Dettinger et al. 1998).

For South Valley, the recent reliability of these climatic characteristics has been one of the primary factors allowing the development of a booming agricultural industry and dramatic increases in human population. The stability of weather and climate in this region is a fairly recent phenomenon, which given projected global climate change may now be short-lived, resulting in some predictable and unpredictable consequences for modern residents, businesses, crops, and ecological processes.

Long-term climatic trends

The most recent Ice Age ended roughly 10,000 years ago, by which time most glaciers and ice sheets had retreated to near their current position (Raab and Jones 2004). The current climatic era, often referred to as the "interglacial period," has been on average warmer and wetter than previous climatic periods. Reconstructions of earlier climate patterns in this Holocene interglacial period have been the focus of significant research in order to determine where our current climate falls within the recent, natural range of Earth's climatic variability, and to reveal possible anthropogenic causative factors affecting climate change.

The depth and resolution at which we are able to reconstruct past climates has increased dramatically in recent decades. On a global scale, ice cores from both poles reveal changes in atmospheric gases going back hundreds of thousands of years (Spahni et al. 2005). At local and regional scales, tree rings and tree-line elevations, sediment cores from montane lakes, meadows, and the ocean floor, and analysis of flood plain stratigraphies reveal climate trends going back thousands of years (e.g., Malamud-Roam et al. 2006,2007; Stahle et al. 2001). These act as archives of paleoclimatic information to describe dramatic climate fluctuations that occurred both locally and regionally, during eras prior to European settlement in the region.

Especially for the historic period, one of the most important proxies of early climate is tree ring analysis (Briffa et al. 1992; Stahle et al. 2001; Fye et al. 2003). This proxy yields year-to-year information about moisture availability that spans both historic and prehistoric eras; however, annual growth rings respond to a myriad of climate and biological factors that must be statistically excluded before conclusions may be drawn. Similarly, with other proxies regional climate trends may be revealed, some of which may not reflect local conditions. For example, analyses of sediment deposits may indicate an overall cool/wet period, but may not reveal small-scale punctuations of that period such as extreme drought years. It is often preferable to use a number of proxies, including bay and lake sediments, flood plain stratigraphies, and instrumental data to generate localized historical climate information (Malamud-Roam et al. 2006,2007). Testimonial evidence can then be used to refine a picture of specific, local impacts created by climate trends and events.

Growth patterns of local blue oaks (Meko et al. 2001; Stahle et al. 2001) provide one of the indicators of local climate history. The width of the annual growth rings of these long-lived trees largely corresponds to moisture availability. When this data is compared to sediment cores and other climatic proxies, patterns of drought and deluge emerge that illustrate the dynamic nature of the region's climate. For instance, recent tree ring research by Stahle et al. (2001) reconstructed a 400-year record of rainfall variation. These data put in context extreme events such as the 1930s and 1976-77 droughts.

This and other proxies reveal two major anomalous climatic periods in the Holocene that dramatically affected life within the region and state. Between roughly 900 and 1350 AD, a particularly dry period persisted throughout the west – commonly referred to as the Medieval Climatic Anomaly. Later, between ~1400 and 1800 AD, the Little Ice Age resulted in notably cooler temperatures on the coast and higher average annual rainfall (Raab and Jones 2004; fig. c.1). However, each of these periods were also punctuated by events and/or years of extreme drought (i.e., during the Little Ice Age) or deluge (i.e. during the Medieval Climate Anomaly). More refined climatic reconstructions suggest that many of the most extreme periods of alluvial deposition responsible for the formation of the deep, rich soils of the valleys and floodplains of the Santa Clara Valley actually took place during these punctuations within the Medieval Climate Anomaly. Catastrophic wildfires during this extremely dry period may have exposed vast acreages of bare soil in local watersheds, which was then eroded onto the valleys and floodplains by discrete events within the Medieval Climate Anomaly (Meyer pers. comm.).

Climate during the historical period

Temperature and rainfall data are available for San Francisco since 1850, while more local data for Hollister, Gilroy, and San José are available from 1874. Rainfall data can be corroborated with and compared to local historical and cultural information, as well as the longer term proxies described above.

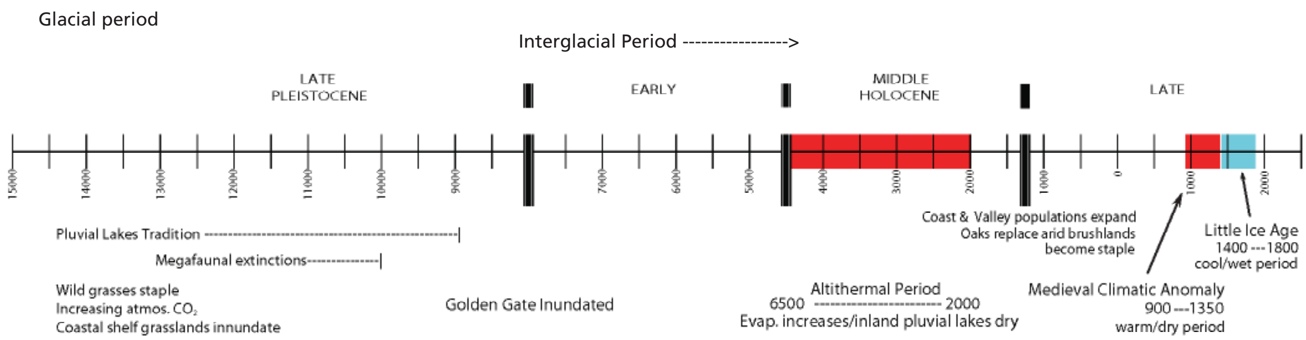

Figure C.1. 15,000 year overview of North American climate. In this figure, the red-shaded areas represent periods of relative warmer and drier climates in the West. The blue represents a cooler/wetter period. As the Late Pleistocene ice age came to a close, glacial melt created vast, inland pluvial lakes, around which human populations concentrated. Lithic and stone assemblages indicate that there was significant utilization of large mammal resources during this period, probably moving climate-stressed megafauna toward their eventual extinction. Increasing atmospheric CO_2 also led to new and plentiful botanical resources. Milling stone technology, useful in preparing wild grass seeds, predominated in this period. The inland pluvial lakes evaporated during the Early/Mid Holocene "Altithermal Period," driving many populations to the coast. During this time, oaks began to replace arid brushlands, ushering in a long period of reliance on acorns in the diet by Native Californians (Raab and Jones 2004).

Climate data for the South Santa Clara Valley area are summarized in fig. c.2. Prior to the development of standardized meteorological data collection, evidence for climatic events can be found in testimony and observations of early explorers, surveyors, and residents. For instance, in 1776, on the way from Llagas Creek to Stevens Creek, Pedro Font noted that the Anza expedition was able to cross marshes near San Juan Bautista due to the lack of rain that year (Bolton and Font 1933). In 1794-95, regional differences in a severe drought year were noted: "[T]he hardest years for the province were 1794 and 1795; but even in those years the drought did not extend over all the territory, so that more than half the average crop was produced" (Bancroft [1890]1970). Writing in 1929, Mylar ([1929]1985) makes note of severe floods more than half a century earlier: "the winter of 1861-1862 was the wettest winter that I ever witnessed in California… The severity of this winter may be judged from the fact that one of these teamsters was drowned in a waterway, a sort of slough, that crossed the road near where Frank Dowdy lives on the road between San Juan and Sargent… The body was afterwards found in the willows near the bridge."

We use the combination of rainfall records, longer-term climatic analyses, and historical accounts of drought and deluge to evaluate the climate context of historical documents. For example, illustrations of stream habitat are considered in relation to the timing of major floods. Similarly, maps of lake or wetland boundaries are compared to corresponding rainfall data to determine whether they reflect extreme or average conditions.

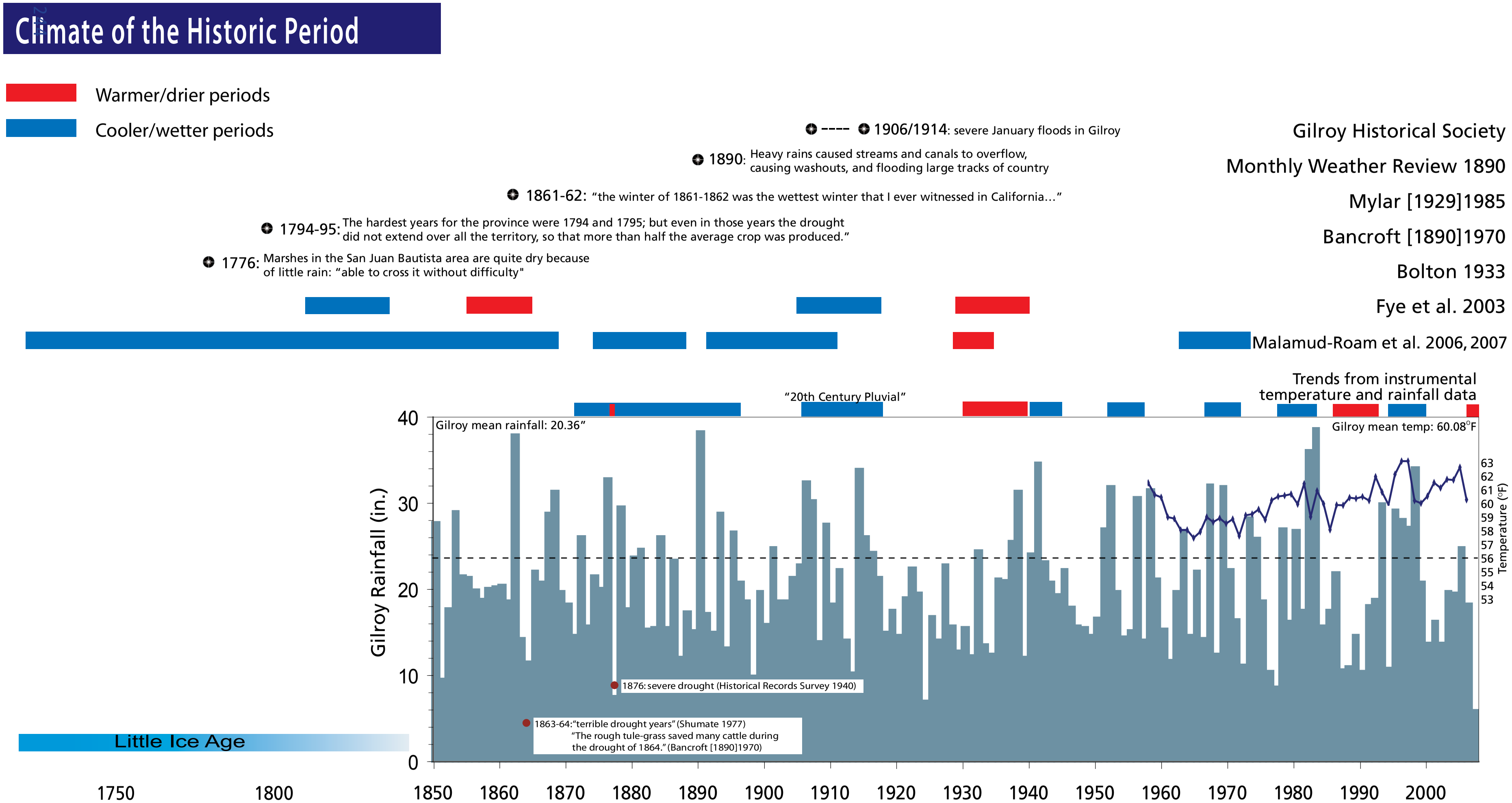

Figure C.2. Climate of the Historic Period: This diagram summarizes several lines of evidence describing the historical climate trends affecting the South Santa Clara County area. Rainfall records from Gilroy are depicted in the lower portion of the figure, and data from other climate proxies are illustrated via text and horizontal bars. Malamud- Roam et al. (2006, 2007) compared a large number of studies which utilized many different climate proxies, including tree ring evidence, accumulated sediment deposits, micro-fossil assemblages, geochemistry, and pollen cores. Fye et al. (2003) compared the Palmer Drought Severity index (PDSI) (based on nationwide tree ring evidence) with instrumental measurements of PSDI to reconstruct periods of decadal extremes in moisture regimes in the West. There is general agreement among the various proxies that outline trends of above and below average rainfall, incidents and periods of flooding and drought, going back thousands of years. These proxies yield year-to-year, decadal, and longer-scale information about moisture availability that span both historic and prehistoric eras. However, regional or larger-scale climate trends may not always reflect local conditions. For instance, analyses of sediment deposits may indicate an overall cool/wet period, but may not reveal small-scale punctuations of that period with extreme drought years. It is often preferable to use a number of proxies, including bay and lake sediments, flood plain stratigraphies, and instrumental data to generate localized historical climate information (Malamud-Roam & Ingram 2006, 2007). Local, testimonial evidence (several sample quotes are shown) can be used to refine a picture of specific, local impacts created by climate trends and events. Note: rainfall data for Gilroy prior to 1874 was extrapolated, via regression, from San Jose rainfall data using the formula ('log10(Gilroy) = 0.848*log10(San Jose)+.319. R2~.73).

APPENDIX 2: HISTORICAL STATUS AND EVIDENCE FOR NATIVE FISH ASSEMBLAGES

(Bold script indicates taxon is endemic to the Sacramento – San Joaquin Zoogeographic Province.)

FAMILY/ SPECIES	ZOO-GEOGRAPHIC TYPE	LIFE HISTORY STATUS	DISTRI-BUTIONAL STATUS	PRIMARY HABITAT OCCURRENCE	NOTABLE EARLY RECORD(S) FROM THE WATERSHED(YEAR) (SOURCE)
PETROMYZONTIDAE/ LAMPREYS *Lampetra tridentata* Pacific lamprey	OBF-SD	M, AND, FWR	P, ?	MR, TC, SC	Pajaro River at Sargent and three miles above Watsonville (Snyder 1912)
CYPRINIDAE/ MINNOWS ***Gila crassicauda*** **thicktail chub**	OBF-FD	FWR	EX	MR, FS, PFP	Soap [San Felipe] Lake (1916)(SU 23795)
Lavinia exilicauda **hitch**	OBF-SD	FWR	LC	MR, FS, PFP	Pajaro River from Watsonville to between Sargent and San Felipe, also "San Felipe [Pacheco Creek] near San Felipe" (1896) (SU 5078, 5979, 22490, Snyder 1912) Llagas Creek near mouth (Snyder 1912) Soap [San Felipe] Lake (1916)(SU 37850) Pacheco Creek (1945)(CAS 19080, 19093, 19095)
Lavinia symmetricus **California roach**	OBF-FD	FWR	LC	MR, TC, SC	Pajaro River at Sargent and above junction with San Benito River (1896) (Snyder 1912) Llagas and Uvas creeks in mountains (1896) (SU 5492, 6061, 22489, Snyder 1912) Pacheco Creek (1945)(CAS 13249, 13259)
Orthodon microlepidotus **Sacramento blackfish**	OBF-FD	FWR	LC	MR, FS, PFP	Pajaro River at Sargent and above and near junction with San Benito River (Snyder 1912) Soap [San Felipe] Lake (1916)(CAS 37876)
Ptychocheilus grandis **Sacramento pikeminnow**	OBF-FD	FWR	P	MR, FS	Pajaro River from Watsonville to between Sargent and San Felipe, also "San Felipe [Pacheco Creek] near San Felipe" (Snyder 1912) Llagas and Uvas creeks in mountains (Snyder 1912)
Rhinichthys osculus **speckled dace**	OBF-FD	FWR	UR	TC	Pajaro River at Watsonville (Snyder 1912) Llagas Creek in mountains (Snyder 1912)
CATOSTIMIDAE/ SUCKERS ***Catostomus occidentalis*** **Sacramento sucker**	OBF-FD	FWR	W	MR, FS, TC, SC, PFP	Pajaro River at Watsonville to between Sargent and San Felipe, also "San Felipe [Pacheco Creek] near San Felipe" (Snyder 1912) Llagas Creek in mountains and near mouth and Uvas Creek in mountains (Snyder 1912) Pacheco, Llagas, and Carnadero creeks (1945)(CAS 13247, 13262, 13258)

FAMILY/ SPECIES	ZOO-GEOGRAPHIC TYPE	LIFE HISTORY STATUS	DISTRI-BUTIONAL STATUS	PRIMARY HABITAT OCCURRENCE	NOTABLE EARLY RECORD(S) FROM THE WATERSHED(YEAR) (SOURCE)
SALMONIDAE/ SALMON & TROUT *Oncorhynchus mykiss* rainbow trout/ steelhead	OBF-SD	M, AND, FWR	LC	MR, TC	Pajaro River at Sargent, at the junction with the San Benito River, and near and three miles above Watsonville (SU 23655, Snyder 1912) Llagas and Uvas creeks in mountains (Snyder 1912) Pacheco and Carnadero creeks (1945)(CAS 13248, 19094, 13256)
GASTEROSTEIDAE/ STICKLEBACKS *Gasterosteus aculeatus* threespine stickleback	OBF-SD	M, EST, AND, FWR	W	MR, FS, TC, PFP	Uvas Creek (1897)(SU 59830) Pajaro River at Sargent and three miles above Watsonville (Snyder 1912) Llagas and Carnadero creeks (1945)(CS 13261, 13257)
COTTIDAE/ SCULPINS *Cottus asper* prickly sculpin	OBF-SD	AMP, EST, FWR	W	MR, FS, TC, SC, PFP	Pajaro River at Sargent (Snyder 1912)
Cottus gulosus riffle sculpin	OBF-FD	FWR	LC	TC	Uvas Creek in mountains (1896, 1897) (SU 5567, 59858, see also Snyder 1912) Llagas Creek in mountains (Snyder 1912) Llagas Creek (1938)(CAS 216474) Carnadero Creek (1945)(CAS 13255)
CENTRARCHIDAE/ SUNFISH ***Archoplites interruptus*** **Sacramento perch**	OBF-FD	FWR	EX	MR, FS, PFP	Pajaro River at Sargent (1896)(USNM 75416) and near junction of the Pajaro and San Benito rivers (Snyder 1912) Pajaro River at Sargent (1927) (SU 24055
EMBIOTOCIDAE/ SURFPERCH ***Hysterocarpus traskii*** **tule perch**	OBF-SD/FD	FWR	EX	MR, FS, PFP	Pajaro River (1892) (SU 5005) Pajaro River at Sargent and three miles above Watsonville (Snyder 1912)

Zoogeographic type: EM = euryhaline marine; OBF-FD = obligatory freshwater dispersant; OBF-SD = obligatory saltwater dispersant.

Life history status: M = marine; AND = anadromous; FWR = freshwater resident; EST = estuarine resident; AMP = amphidromous.

Current distributional status: LC = locally common; W= widespread; UR = uncommon/rare; P = current status and/or population abundance poorly documented or unknown.

Primary habitat occurrence: MR = mainstem river/stream; FS = floodplain sloughs; TC = tributary creek; SC = side channel; VFM = valley freshwater marsh; PFP = perennial freshwater ponds and lakes; ILP = intermittent lakes and ponds.

Source: SU = Stanford University fish collection (housed at CAS, San Francisco); CAS = California Academy of Sciences, San Francisco; USNM = United States National Museum (Smithsonian)

APPENDIX 3: PROBABLE NATIVE FISH ASSEMBLAGES AND MAJOR LOCAL HABITAT TYPES

HABITATS	EXAMPLES (WITH RELEVANT ILLUSTRATIONS)	PROBABLE FISH ASSEMBLAGE SPECIES MEMBERSHIP POOL
STREAM AND RIPARIAN		
Mainstem stream (perennial)	Pajaro River (figs. 4.24 and 4.25)	Pacific lamprey, thicktail chub, hitch, California roach, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, steelhead (primarily as migration corridor for adults and smolts), threespine stickleback, prickly sculpin, Sacramento perch, tule perch
Mainstem stream (intermittent)	Low- to mid-elevation Pacheco Creek (fig. 4.30)	Pacific lamprey (migration corridor), rainbow trout/steelhead (primarily as migration corridor for adults and smolts), hitch, California roach, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin
Large discontinuous creeks and distributaries	Lowermost Uvas-Carnadero, Llagas, and Pacheco creeks (fig. 7.14)	Assemblage likely highly variable depending on local environmental conditions. On lower Llagas Creek discontinuous channels were associated with perennial valley freshwater marsh assemblage (i.e., "tule swamp"). Further upstream, intermittent channels likely supported species characteristic of large tributary habitats interspersed with dry fishless reaches on highly permeable alluvial soils (see below).
Small discontinuous creeks and distributaries	Many small creeks descending from foothills onto permeable alluvial fans (fig. 4.7); see also Crews and San Ysidro creeks (fig. 7.2)	Typically fishless unless associated with wetland habitat (see below).
Floodplain sloughs	Tequisquita Slough (figs. 4.9, 4.10)	Thicktail chub, hitch, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin, Sacramento perch, tule perch
Large tributary creek (perennial mainstem)	Uvas-Carnadero and Pacheco creeks (fig. 7.13)	Pacific lamprey, rainbow trout/steelhead, hitch, California roach, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, riffle sculpin
Large tributary creek (intermittent mainstem)	Llagas and Pacheco creeks	Pacific lamprey (migration corridor), rainbow trout/steelhead (primarily as migration corridor for adults and smolts), hitch, California roach, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, prickly sculpin
Small tributary creek (perennial-to-intermittent headwater)	Uvas-Carnadero, Llagas, Bodfish, Little Arthur, Cedar, and South Fork Pacheco creeks	Pacific lamprey, rainbow trout/steelhead, California roach, Sacramento sucker, threespine stickleback, riffle sculpin
WETLAND HABITATS		
Perennial freshwater ponds, lakes, and lagoons	San Felipe Lake (figs. 5.9, 7.27 and 7.28)	Thicktail chub, hitch, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, prickly sculpin, threespine stickleback, Sacramento perch, tule perch
Intermittent ponds, lakes, and lagoons	Pajaro Lake (fig. 5.10)	Thicktail chub, hitch, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, prickly sculpin, threespine stickleback, Sacramento perch, tule perch
Perennial valley freshwater marsh	Confluences of Miller Slough, Llagas and Uvas-Carnadero creeks with the Pajaro River; Tequisquita Slough (fig. 5.8)	Thicktail chub, hitch, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, prickly sculpin, threespine stickleback, Sacramento perch, tule perch

Notes: The probable fish assemblage species membership pool was derived from historical and recent records and accounts of fish occurrences within the context of historical environmental conditions. Historical fish assemblage diversity and species abundances for each habitat type would likely exhibit significant temporal and spatial variability, and would be contingent on local topography, soils, geology, and annual rainfall patterns, among other environmental factors. For example, habitat suitable for rainbow trout/steelhead immigration, spawning, rearing, and emigration would vary temporally along several environmental axes, most notably the amount and distribution of annual precipitation, the influences of local and regional landform and geology on the spatial distribution, diversity, and persistence of surface water habitats, water temperature, the suitability of spawning substrate, rearing habitat availability, and food quality and quantity. This table presents the larger-scale distributional patterns, within which finer-scale variation would be expected to occur.

Sources: Snyder (1912), Smith (1982, 1998, 2007a,b), Gobalet (1990), California Academy of Sciences Ichthyology Collection Database (accessed May 2008).