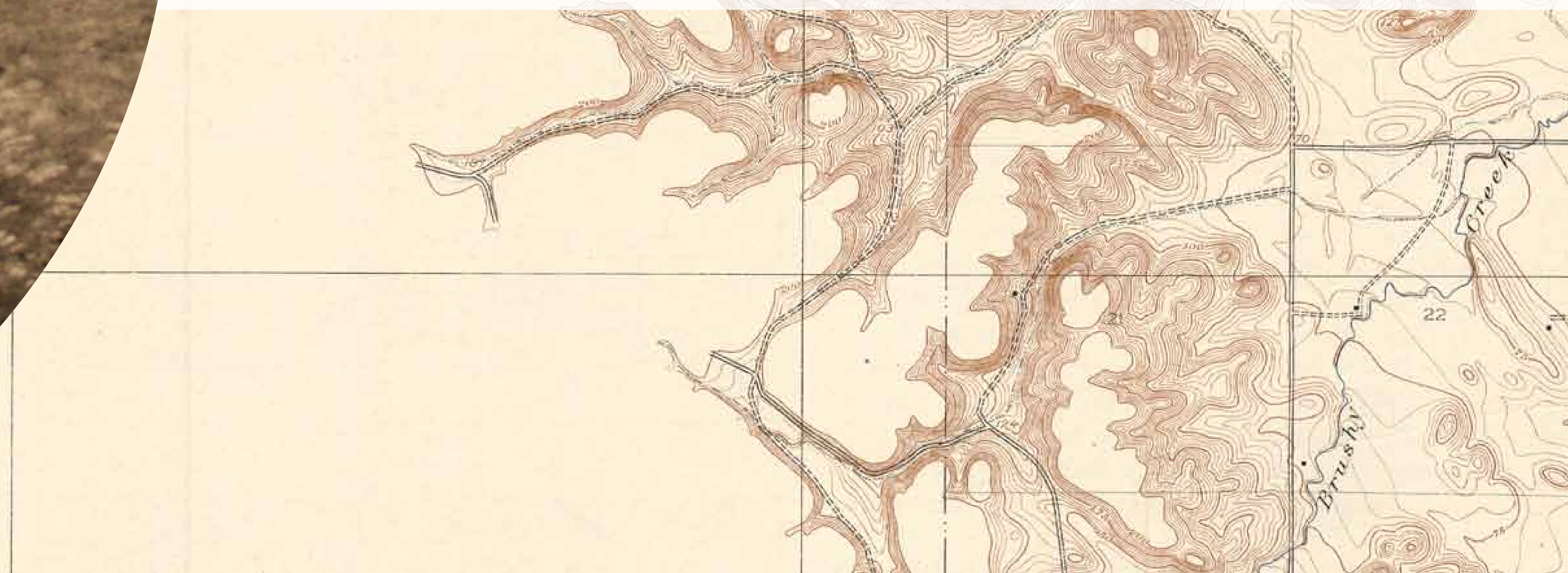
EAST CONTRA COSTA COUNTY HISTORICAL ECOLOGY STUDY

NOVEMBER 2011

SAN FRANCISCO ESTUARY INSTITUTE



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Report and GIS layers are available on SFEI's website, at www.sfei.org/HEEastContraCosta.

Front cover: Views of East Contra Costa County through time. Top: View from Fox Ridge west towards Mount Diablo, 2010; Middle: Kellogg Creek, ca. 1920 "In NW 1/4 sec. 3, 2S, 2E, on road slope from hill looking N. along Kellogg Creek"; Bottom: Detail from USGS 1916 (Byron Hot Springs quad).

Contemporary photo February 23, 2010 by Abigail Fateman. Historical photo courtesy of the California Historical Society.

Title page: View of Kellogg Creek watershed, looking south toward Brushy Peak, ca. 1920. Near present-day Los Vaqueros Reservoir on section 21 (SE quarter) Township 1 South, Range 2 East.
Courtesy of the California Historical Society.

EAST CONTRA COSTA COUNTY HISTORICAL ECOLOGY STUDY

PREPARED FOR CONTRA COSTA COUNTY • NOVEMBER 2011
SAN FRANCISCO ESTUARY INSTITUTE

Prepared by:

SAN FRANCISCO ESTUARY INSTITUTE

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In Cooperation with:

CONTRA COSTA WATERSHED FORUM

CONTRA COSTA COUNTY
DEPARTMENT OF CONSERVATION AND DEVELOPMENT

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CONTRA COSTA COUNTY
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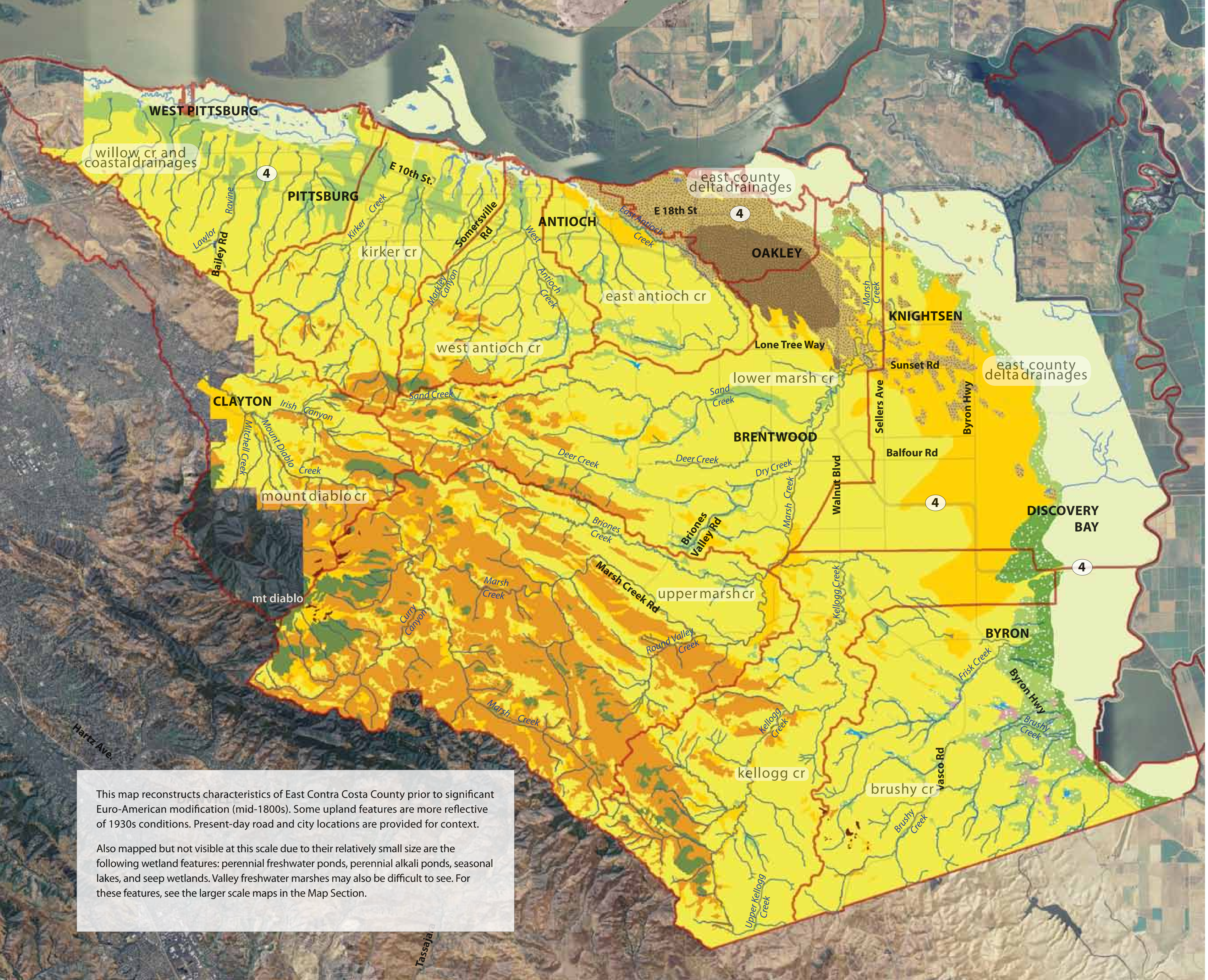
Fish and Wildlife Committee



This map reconstructs characteristics of East Contra Costa County prior to significant Euro-American modification (mid-1800s). Some upland features are more reflective of 1930s conditions. Present-day road and city locations are provided for context.

Also mapped but not visible at this scale due to their relatively small size are the following wetland features: perennial freshwater ponds, perennial alkali ponds, seasonal lakes, and seep wetlands. Valley freshwater marshes may also be difficult to see. For these features, see the larger scale maps in the Map Section.

HISTORICAL LAND COVER, mid-1800s

- Tidal Marsh, Pond, Slough
- Valley Freshwater Marsh
- Wet Meadow
- Alkali Meadow
- Alkali Sink Scrub
- Alkali Flat
- Alkali Marsh
- Woodland
- Oak Savanna
- Chaparral
- Grassland
- Interior Dune Scrub
- Interior Dune (veg. undefined)
- Rock Outcrops
- Stream
- Distributary
- marsh Watershed Boundary

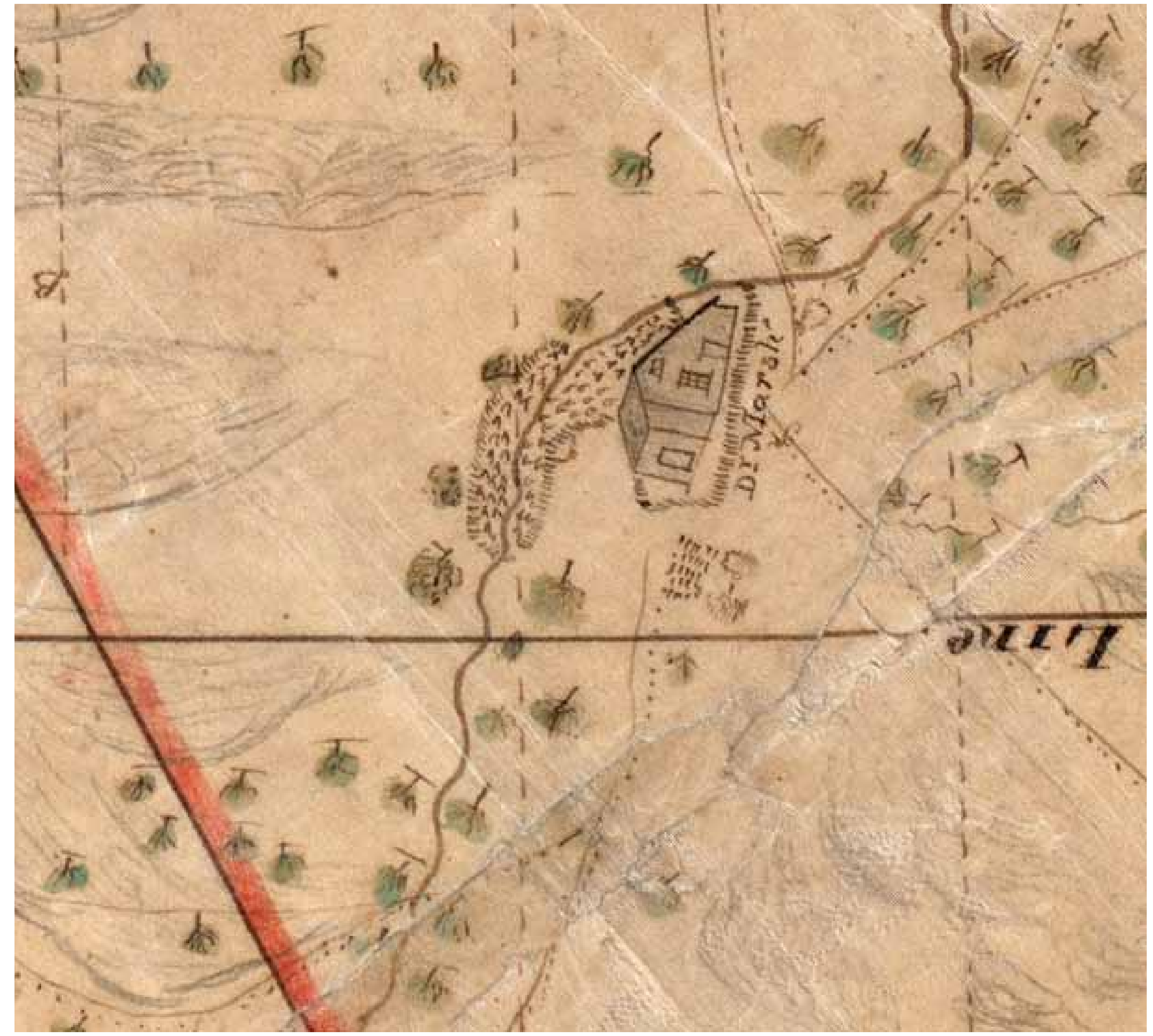
USDA 2005, courtesy of NAIP

CONTENTS

FIGURES

TABLES

BOXED TEXT



ACKNOWLEDGMENTS

This project was funded by the California State Coastal Conservancy, the Contra Costa County Department of Conservation and Development, the Contra Costa County Flood Control and Water Conservation District, the California Department of Fish and Game, the Contra Costa County GIS Policy Committee, and the Contra Costa County Fish and Wildlife Committee.

The depth and breadth of research we achieved with this project was only possible with the assistance of archivists at many institutions, including The Bancroft Library and the Water Resources Center Archives at UC Berkeley, the California Historical Society, the Peter J. Shields Library at UC Davis, the State Lands Commission, and the Society of California Pioneers. We were able to access three key sources thanks to staff at additional institutions - both the Earth Sciences & Map Library of UC Berkeley and Contra Costa County Public Works contributed early aerial photos; staff at the Bureau of Land Management provided early General Land Office surveys; and James Thorne at UC-Davis provided access to the Wieslander dataset.

We received assistance from historians at historical societies throughout the county, including the East Contra Costa Historical Society in Brentwood, the Contra Costa County Historical Society in Martinez, the Antioch Historical Society, the Pittsburg Historical Society, and the Clayton Historical Society. These historical societies were extremely valuable resources for maps and photographs, and we are indebted to the many historians who assisted us.

Staff from Contra Costa County and the East Contra Costa County Habitat Conservancy contributed time, expertise, and guidance in the conceptualization and execution of this project. In particular, we are grateful for the assistance and support we received from Abigail Fateman and John Kopchik throughout this project. Chris Howard and Michael Isip contributed work on the aerial photograph mosaic, and staff at the Recorder's Office and Ed Turner at the Public Works Department assisted by locating maps and other data. Allison Bateate at the Contra Costa Water District gave us access to reports on Los Vaqueros, and Mary Grimm from the Resource Conservation District forwarded portions of relevant reports. Mitch Avalon of the Contra Costa County Flood Control and Water Conservation District provided additional support and feedback.

We received invaluable input from local residents through meetings with the Contra Costa Watershed Forum and the Friends of Marsh Creek Watershed. Tours of Byron Hot Springs, Vasco Caves, and Antioch Dunes helped us gain a deeper understanding of and appreciation for the region. The East Contra Costa Historical Society and the Tracy Historical Museum provided access to the Byron Hot Springs; East Bay Regional Park Service provided a tour of Vasco Caves; and the US Fish and Wildlife Service provided a tour of the Antioch Dunes area.

We would like to thank our technical review team for contributing their expertise and local knowledge to the project. Reviewers for this report were Seth Adams, Heath Bartosh, Doug Bell, Abigail Fateman, Todd Keeler-Wolf, John Kopchik, Chris Thayer, Jim Thorne, Rich Walkling, and David Zippin.

This project built on work completed by others in this region, including the Contra Costa County Watershed Atlas and extensive work completed by the East Contra Costa County Habitat Conservation Plan Association and Jones & Stokes to create the Habitat Conservation Plan/Natural Community Conservation Plan. In addition, we drew upon a series of reports by the Natural Heritage Institute covering Marsh Creek, Dutch Slough, and Mt. Diablo Creek. We thank Sean Micallef for sending a copy of his thesis, and Sheila Barry and Cyndy Shafer for contributing additional reference materials. Seth Adams, Steve Edwards, and Pete Englehart contributed information on the cultural and ecological history of the region.

We received in-house technical assistance from Marcus Klatt, Sarah Pearce, Linda Wancyzk, Dave Bollinger, and Gregory Tseng. Additional thanks go to Frank Davis and Josh Collins for technical advice and review concerning our interpretation and mapping of dryland vegetation.

Most of the contemporary photographs in this report were contributed by Save Mount Diablo and by Abigail Fateman of Contra Costa County.

Two interns through the Bill Lane Center for the American West at Stanford University contributed to this project. Intern Darcy McRose assisted with initial data collection, and Alec Norton helped with GIS compilation and synthesis.

CHAPTER 1
INTRODUCTION

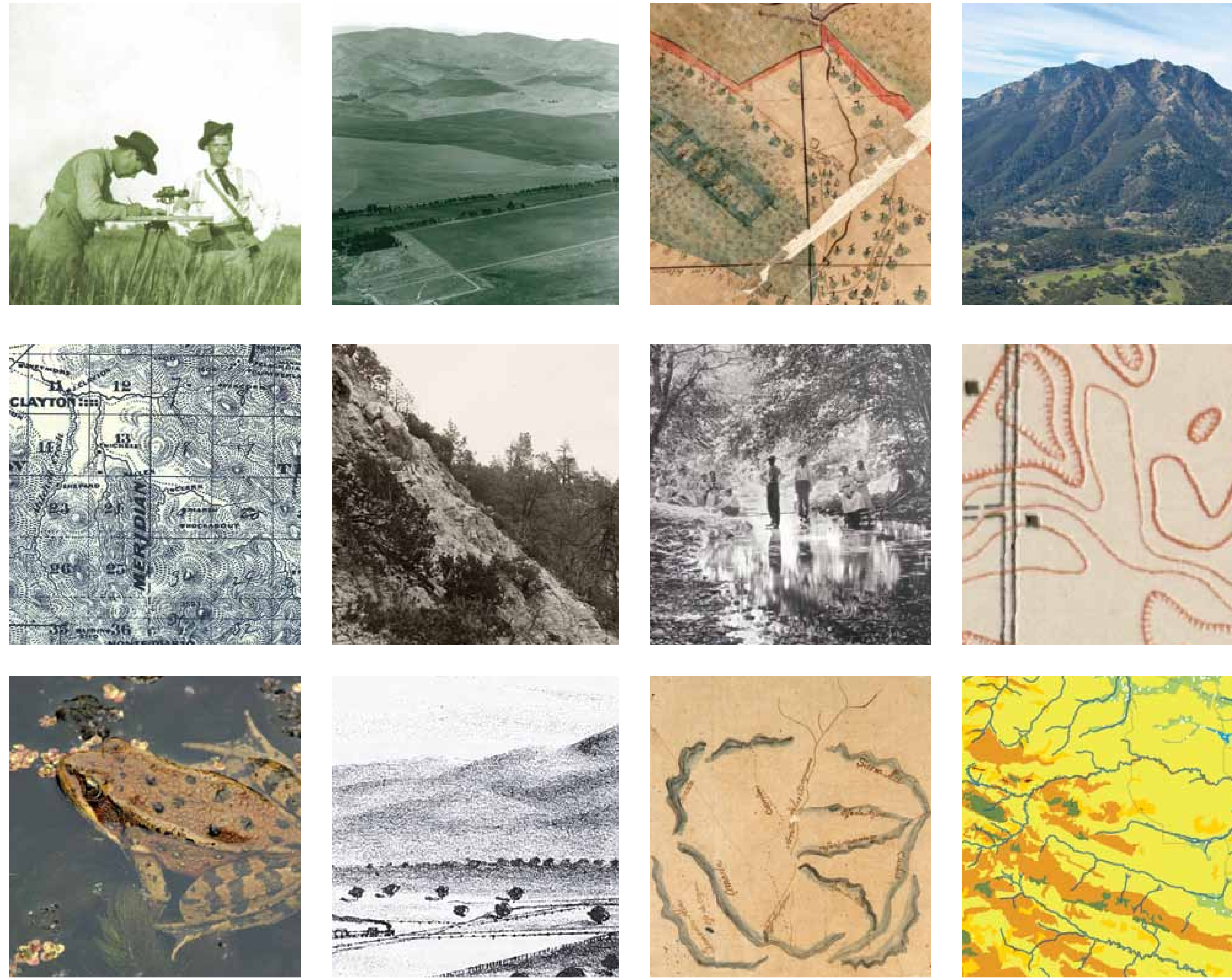
Standing on the summit of Mount Diablo, that cone-like pinnacle...a panoramic view is obtained that, however gifted, no artist's brush could paint or pen faithfully portray. It is simply a wonderful and interesting picture a of valley 'cradled in the hills,' of farms, orchards, hamlets, towns, cities – long stretches of watercourses, silvery in the sunlight – great bays and far-reaching inlets, with sail and steam craft crawling on their surface like flies on a gigantic mirror – vast areas of plains – the islands of the great delta of the Sacramento and San Joaquin rivers; and beyond, dim in the distance, the Sierras lift their lofty and luminous summits, snow-crested, into the imperial blue of unclouded skies.

—R.G. DEAN IN HULANISKI 1917

East Contra Costa County is a complex and ecologically important region. It is topographically diverse, ranging in elevation from Mount Diablo at 3,849 feet to the tidelands of the Sacramento-San Joaquin Delta which lie at or below sea level. The region is also climatically diverse: while the western edge receives some marine influence, the east lacks this moderating force and can become hot and dry – rainfall varies from 13 to 23 inches per year (Jones & Stokes 2006). Finally, the region has a complex geology as a result of the uplift that created Mount Diablo. These factors combine to create highly variable soils and a wide range of land cover types (fig. 1.1). Historically, a patchwork of chaparral, savanna, grassland, and woodland covered the hills; intermittent and ephemeral streams drained into wet meadows in the north; a swath of dense interior dune scrub covered 2,800 acres in the northeast; and alkali wetland complexes spread towards tidal marsh in the southeast.

Although substantial portions of East Contra Costa County remain relatively undeveloped, extensive landscape change has occurred over the past 200 years. Many habitats have been lost or altered, particularly in the more intensively developed lower elevations. Many questions exist about the pre-modification distribution of habitats, the processes that controlled their formation and maintenance, and the changes that have resulted from historical land use. The study of historical ecology can address these information gaps, providing a critical foundation for successful environmental planning (NRC 1992, Montgomery 2008). Through comparison to contemporary conditions, historical ecological research can identify new conservation strategies that could not have been recognized without historical information (e.g., Grossinger et al. 2007, Walter and Merritts 2008).

Figure 1.1. Historical ecology of East Contra Costa County: a sampling of graphics used throughout the report.



Historical ecology seeks to describe historical landscape patterns to improve understanding and management of the contemporary landscape. The goal of this report is to document landscape features as they existed, on average, during the first decades of Euro-American settlement, and to help translate this information into useful tools for present-day land managers, scientists, and residents. To do this, we synthesized an array of records documenting the landscapes of East Contra Costa County prior to significant Euro-American modification. This report and the associated geo-database provide a spatially comprehensive dataset documenting the distribution, and abundance of the historical native habitats of East Contra Costa County. The approximate time period for our historical habitat map is the mid-1800s, although portions of the map (including the uplands) are more representative of 1930s conditions. The mid-1800s is the earliest date with enough historical evidence to support our mapping process. We did not attempt to exhaustively document land use history or record all changes that have occurred since European contact. Rather, the focus is on describing ecological and landscape-level patterns across the region.

DESIGNING RESILIENT LANDSCAPES:

HISTORICAL ECOLOGY, RESTORATION, AND CLIMATE CHANGE

Restoration goals should be informed by knowledge of landscape conditions before modern development. Historical ecology research improves our understanding of the habitats we seek to restore, including the physical and cultural processes that governed their former distribution. Studying the landscape under earlier, less impacted conditions facilitates a landscape perspective that addresses questions fundamental to the restoration planning process: What habitats were supported where, and why? Where have certain habitats persisted? How have landscape patterns and process changed over time? Most importantly, how do we choose appropriate restoration and management targets?

Historical ecology has particular relevance to these questions in the context of global climate change. As we anticipate a more variable climate in the future, we can learn from the ways in which dynamic historical ecosystems were able to respond and adapt to extreme conditions in the past. The harsh semi-arid conditions of East Contra Costa County supported plant communities adapted to low rainfall and high temperatures, including alkali communities and the Oakley sand dune scrub. Embracing and understanding these communities may help us design more resilient, well-adapted suites of plant species in the future.

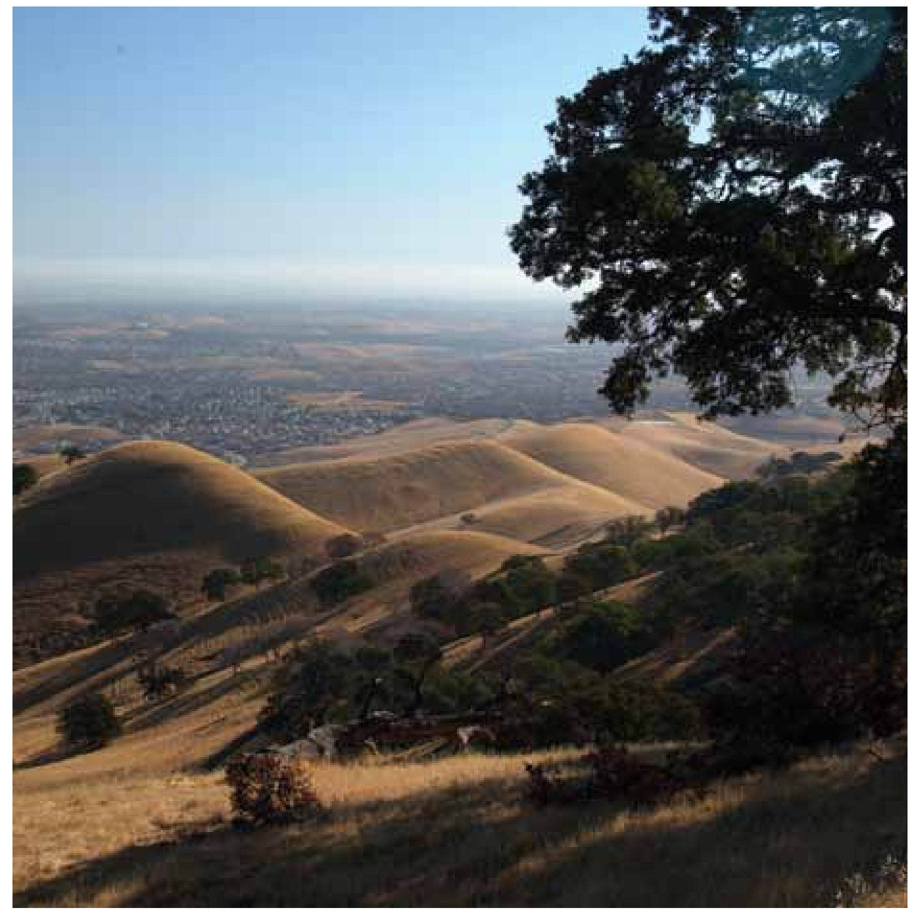


Figure 1.2. ECCC, urban and rural. (September 30, 2001, by Scott Hein, www.heinphoto.com)

Historical ecology is an essential component of restoration design, but it is not an answer in and of itself. It is a tool for scientists and managers seeking to understand and recover from the dramatic landscape changes of the past 250 years. When integrated with contemporary data and future projections, historical information helps identify restoration opportunities and develop realistic management strategies. Often these would not be recognized without a historical perspective. Though controls on habitat distribution such as land use and climate may change, others, such as topography and geology, remain relatively stable (fig. 1.2). Historical ecology helps us understand which characteristics supported native species of concern and how these can be recovered or enhanced. Understanding the landscape patterns and processes of the recent past can help us establish functional, resilient systems that improve the ecological health of the region.

The recently adopted East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP, here referred to as the HCP) and other local environmental planning efforts have recognized the need for a better understanding of the historical ecology of the area to inform the protection, restoration, and enhancement of local natural resources. Accordingly, this historical analysis has been developed to inform strategies for habitat restoration and conservation, acquisition priorities, natural flood protection, parkland management, and other environmental management activities. An important goal of many restoration projects is to reestablish site conditions that existed historically in order to enhance ecosystem function and habitat for local endangered and threatened species. The HCP also calls for improved management in many upland communities. This report is intended to help inform the design and implementation of these and other restoration and enhancement projects. This information is also made publicly available as a tool for future research and an information resource for other local and regional planning efforts. The report and accompanying GIS data can be downloaded from www.sfei.org/HEEastContraCosta.

Today East Contra Costa County is home to over 250,000 people. Brentwood grew 120% between 2000 and 2010, and the region as a whole added over 50,000 residents (U. S. Census Bureau 2010). However, many undeveloped and protected spaces remain. Urban development covered 19% of the HCP area in 2006, with agriculture (primarily croplands) covering an additional 22% (Jones & Stokes 2006). Alkali, dryland, and wetland habitats (including reservoirs and non-native woodlands) covered 57% of the study area.

This study focuses on the 174,018 acre area covered by the HCP, plus adjacent tidal marshlands (fig. 1.3). Throughout this report, we refer to the study area as East Contra Costa County, or ECCC. The ECCC study area covers approximately one-third of Contra Costa County (187,230 acres). On the south side, the boundary follows the county line with Alameda County. The southwest boundary follows the watershed divide that separates the Alameda Creek watershed (draining to the Bay) from creeks to the east that drain to the Delta. The city limits of Clayton and Concord form the western and northwestern boundaries. The northern boundary extends beyond that of the HCP to incorporate the tidal habitats of the Sacramento-San Joaquin River. The eastern boundary follows that of the HCP inventory area except for an extension to the east beyond the town of Discovery Bay.

We begin the report with a general discussion of research methods and an overview of historical land use in the region to provide context for our findings. We then review and analyze our results for each of three broad habitat classes: streams and riparian habitats, wetland habitats, and dryland habitats. For each habitat class we present methods, results, and discussion of key findings. At the end of each chapter is a boxed text including a summary of findings and management implications for the chapter. Appendices discuss additional methods in greater detail.

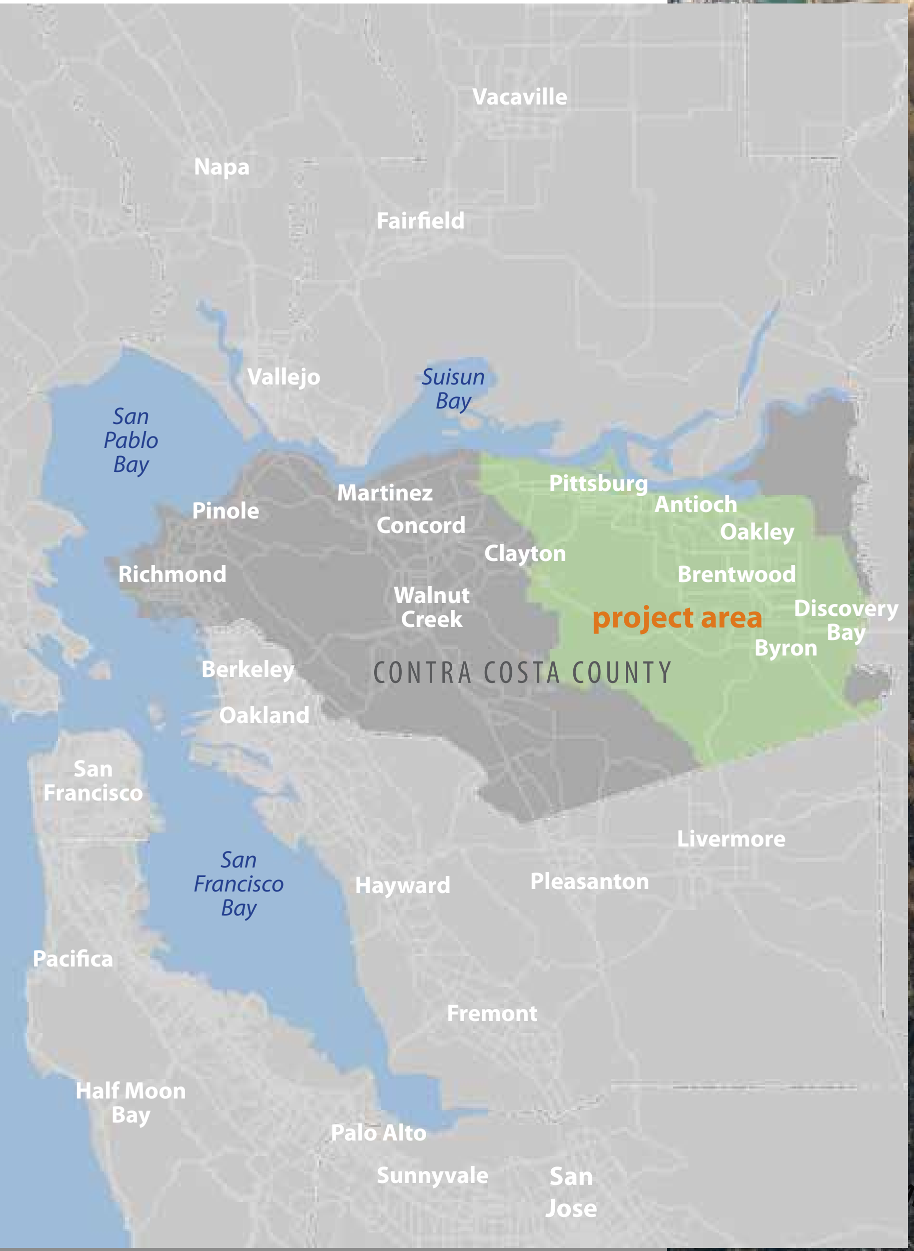


Figure 1.3. Study area and geographic locator map. The study area is in light green in the inset above and outlined in orange on the map at right. The contemporary stream network is shown on top of the aerial imagery. (Imagery USDA 2005, courtesy of NAIP)

DIFFERING PERSPECTIVES ON EAST CONTRA COSTA COUNTY

East Contra Costa County has alternately charmed and dismayed visitors for centuries. Explorers and travelers from Europe and the eastern United States had difficulty appreciating the American West, and found the vastness of the landscape and the relatively dry climate unsettling (Hyde 1993, Stegner 2002). Their expectations, combined with the seasonal and regional variability of the region resulted in a range of somewhat contradictory descriptions.

In particular, the plains north and east of Mount Diablo often evoked uneasy responses from early visitors and settlers, who were struck by the barren and dry landscape. Prospectors passing Pittsburg en route to the gold mines in the Sierra foothills were dismissive of the northern shoreline, and one gold seeker from Ireland noted "this is a wretched looking town + I think will never come to any great note…its *[sic]* built on very low swampy ground, up to this I may say that the land along the banks is not of much value being of a barren nature" (Kerr 1850). William Brewer, the chief botanist for the California Geological Survey (fig. 1.4), lamented in October of 1861 that there were "no trees to cheer the eye, no water in the many canyons and ravines…found no water for self or mule, except some alkaline springs which neither mule nor I could drink"(1974).

However, over time residents came to describe even these plains in more favorable terms, noting the oaks, wildflower displays, and agricultural productivity: "The country is beautified by live oaks...It is a charming drive through this brushy, varied tract to Brentwood, especially when spring has spread the ground with a carpet of many colors, white, crimson, purple and yellow, in large continuous patches" (*Contra Costa Gazette* 1887). Although the East Contra Costa plains were largely cleared for agriculture, farm and ranch houses were usually situated by clumps of remaining trees, or by ornamental trees that were planted to supplement or replace the native oaks (Smith and Elliot 1879). Remnants of the savanna after agricultural clearing can be seen in historical aerial photos and contemporary imagery, as in figure 1.5, showing an area by Point of Timber Road west of Discovery Bay.

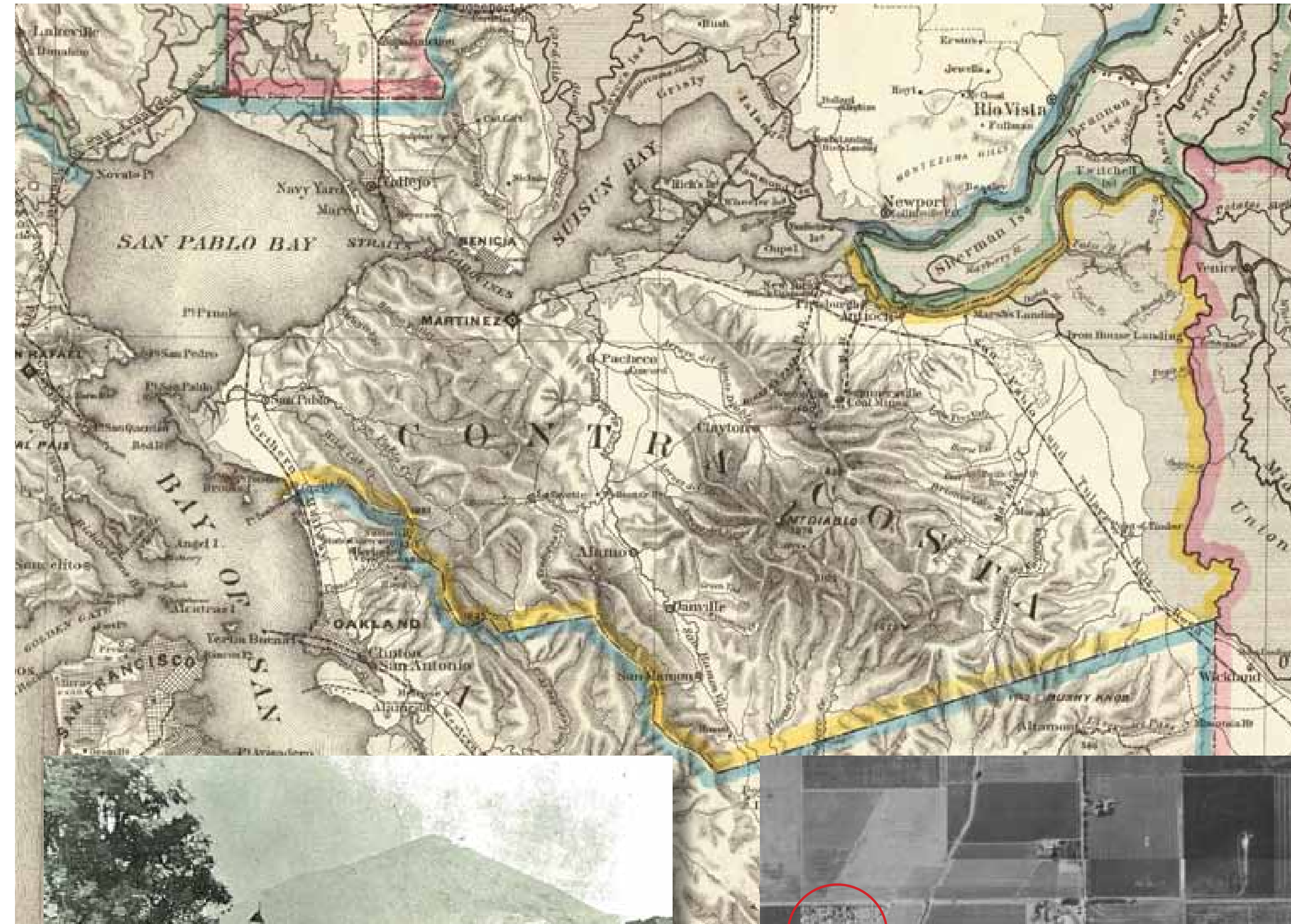
Views across the county from Mount Diablo were also often described in glowing terms. Josiah Whitney, Chief of the California Geological Survey, was particularly impressed:

> The view from the summit is magnificent…around the base of the mountain you behold, in all the elegance of their graceful outline and the beauty of their light and shadow, the admirably rounded foothills, gradually diminishing in prominence until they merge with the delightful valleys through whose groves of wide-spreading oaks and sycamores the eye involuntarily traces out the meandering courses of the sparkling waters, that, after having dashed down their rugged mountain channels, appear to delight to linger amid the scenes of beauty with which they are surrounded. (Contra Costa County 1887)

Early settlers learned to appreciate the unique nature of the area, and to understand to the seasonal variability of rainfall. In May of 1862 – the spring of a year with record rainfall, and six months after the quote above – Brewer's perspective had changed:

> Everything has 'greened up' marvelously, and this region, so brown, dry, dusty, and parched when we visited it last fall, is now green and lovely, as only California can be in the spring. Flowers in the greatest profusion and richest colors adorn hills and valleys and the scattered trees are of the liveliest and richest green. (Brewer 1974)

The xeric nature of East Contra Costa continues to challenge our conceptions of how a system 'should' work. By carefully uncovering the story of the ecological past we can hopefully learn to adapt more fully to this varied and rich region.



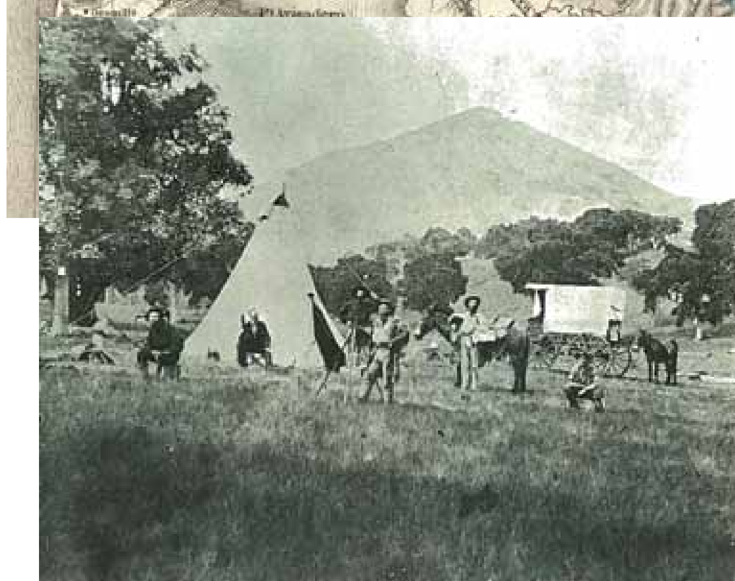


Figure 1.4. Map and field work by the California Geological Survey. Top: a portion of the Topographical Map of Central California by Josiah Whitney and Charles Hoffman, published in 1873, showing Contra Costa County. Bottom: a California Geological Survey field camp at Clayton in 1862. From left to right are members of the surveying party: William Gabb, Josiah Whitney, Chester Averill, Charles Hoffman, William Brewer, Schmidt (the cook, first name unknown). (Top: Whitney 1873, courtesy David Rumsey; Bottom: University of California Press)

Figure 1.5. Trees on the former oak savanna near Discovery Bay. (Top: USDA 1939, courtesy of CCC and Earth Sciences & Map Library, UC Berkeley; Bottom: USDA 2005, courtesy of NAIP)

CHAPTER 2
GENERAL METHODS

I cannot say that I understand this diseño, it has no scale on it and nothing to show how much land it is intended to contain.

– William W. Smith 1855, first alcade of New York of the Pacific,
Contra Costa resident since 1849,
speaking of Los Medanos *diseño*, made ca. 1839

To reconstruct the past landscape of East Contra Costa County, we collected hundreds of historical textual and graphic records, and synthesized these with useful contemporary datasets such as soils, topography, hydrology, and vegetation. This section describes the general methods used throughout the study. Additional description of methods specific to each habitat type is provided in the landscape analysis chapters.

DATA COLLECTION

A substantial variety and quantity of historical data are needed for an accurate assessment of the historical landscape (Grossinger 2005). With this in mind, we assembled a diverse range of records spanning more than two centuries. We then compiled these data into a map of historical landscape patterns as we believe they existed around 1850.

Assembled materials included textual data (e.g., Spanish explorers' accounts, Mexican land grant case court testimonies, Public Land Survey records, early travelogues, and Contra Costa County histories and reports), maps (e.g., Mexican land grant maps, early city and county maps and surveys, USDA soil surveys, and US Geological Survey maps; fig. 2.1, 2.2), and paintings and photography (both ground-based and aerial). We used a customized Endnote database to catalogue these historical data sources and produce bibliographies.

To acquire these sources, we visited local historical archives (e.g., Contra Costa County Historical Society, East Contra Costa Historical Society and Museum, Pittsburg Historical Society), county offices (e.g., Contra Costa County Public Works Department, Contra Costa County Recorder's Office), and regional archives (e.g., 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 Library of Congress Online Catalog, and others. Early aerial photographs covering the study area were acquired and scanned through a partnership with the Earth Sciences & Map Library at the University of California, Berkeley.

Figure 2.1. U.S. Geological Survey (USGS). Top row: (A) detail from a Meganos land grant map by A.W. Von Schmidt in 1861; (B) a surveying compass which was used by early surveyors to measure direction; and (C) a portion of a USGS map near Antioch. (D) Surveyors in the field ca. 1925 working with an alidade and a plane table. The alidade was used to sight an object and draw a line or angle on the plane table during the construction of a topographic map. (A: Los Meganos land grant map, courtesy The Bancroft Library, UC Berkeley; B: courtesy U.S. Geological Survey; C: USGS 1918 (Collinsville), D: USGS ca. 1925, courtesy U.S. Geological Survey)

Figure 2.2. Rancho de Los Meganos, J. E. Whitcher, 1853(a). This map depicting the extent of John Marsh's land grant claim is remarkably informative. Natural landmarks depicted include stream channels, springs, alkali flats, tidal marsh, and areas of oak savanna. While many land grant maps are not to scale and show only the general relationship between features rather than precise locations, this map is highly accurate. Whitcher, an experienced surveyor, added township, range, and section lines, which allow for accurate depictions within each section of the map. The map is shown georeferenced in the inset at right but the map below is as Whitcher oriented it, with the San Joaquin River and Marsh's Landing as the primary points of entry. The original map measures approximately 34 inches wide by 28 inches high. For each numbered point below, an illustration with additional map sources is shown in the boxed text on the opposite page. (Courtesy of The Bancroft Library, UC Berkeley)

We collected two additional specialized and highly detailed sources. Public Land Survey (PLS) data produced by the General Land Office (GLO) cover the entire study area in a one mile grid, excluding land grants. The GLO survey came to Contra Costa County in 1851 and provides detailed point information on stream crossings and vegetation (see box text on p.11 and further discussion in Chapter 6, p.75). Additional vegetation information came from a dataset produced under Alfred Wieslander in the 1930s, which we were able to acquire as vectorized polygons from Jim Thorne of the Information Center for the Environment (ICE) at the University of California, Davis.

We reviewed an estimated 6,000 historical documents (maps, photographs, and written materials) and acquired full or partial copies of over 2,000. This variety of documents from different eras allowed us to use independent sources to intercalibrate or triangulate landscape features (Grossinger et al. 2007). 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 further refinement of our understanding of the local landscape.

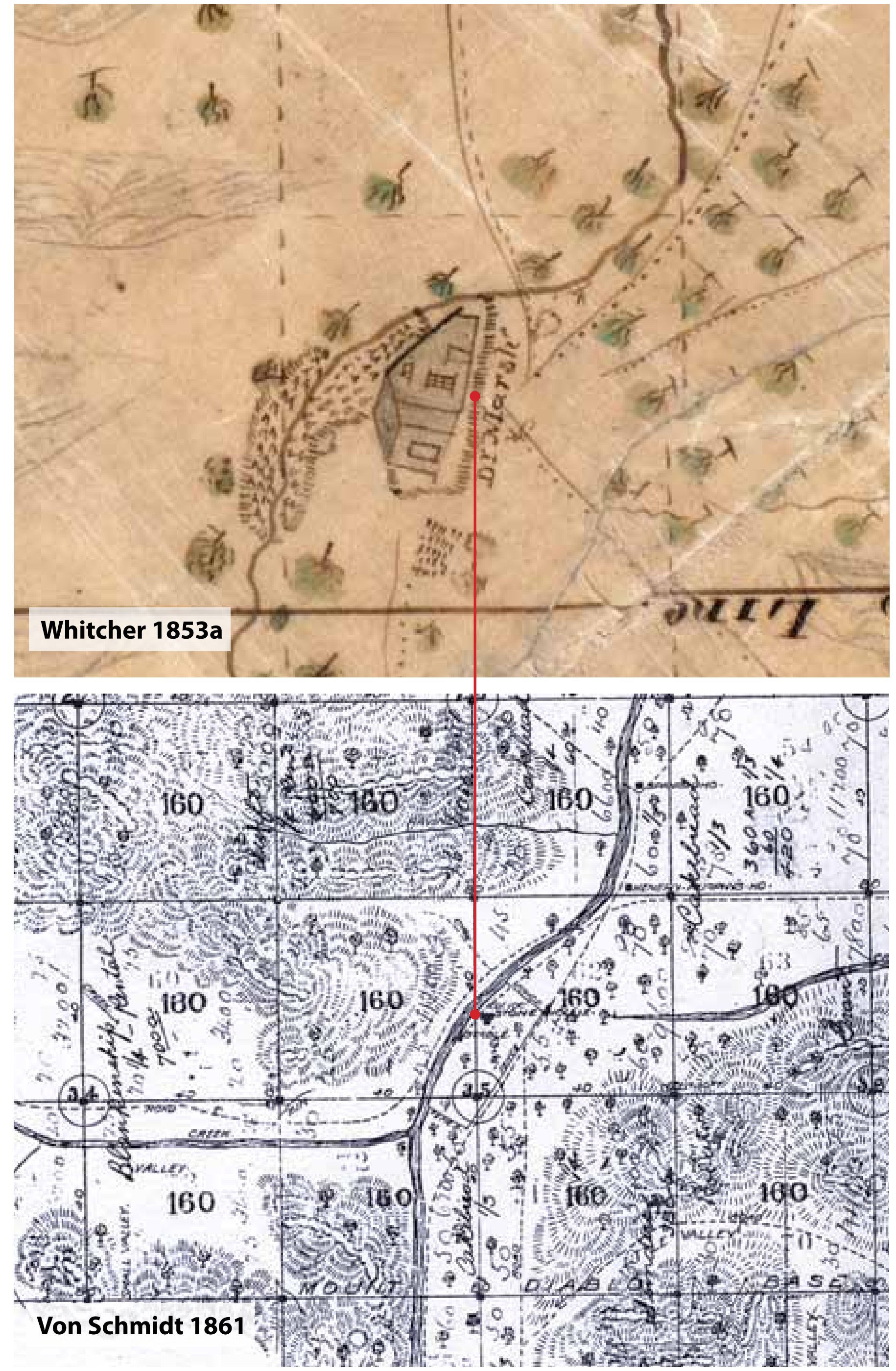
INTERPRETATION OF HISTORICAL DOCUMENTS

Accurate interpretation of documents produced during different eras, within differing social contexts, and by different authors, surveyors, or artists can be challenging (Harley 1989, Askevold 2005, Grossinger and Askevold 2005). To address these concerns, we used a number of independently-produced documents, covering a range of eras, 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 the unavoidable absence of replicate samples and predetermined methods (Grossinger 2005, Grossinger and Askevold 2005; see box at right).

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). Land use was much more variable during this time, so we focused on differentiating natural and anthropogenic features. We were careful to map only features that were not the result of agriculture or other 19th century land use or extreme climatic periods. Quantitative and textual descriptions of climatic conditions (floods, droughts, and rainfall) and land use regimes (native management, grazing, dry-farmed agriculture, 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, GLO survey data describing a pond approximately 30 meters wide was supported by a depiction of a lake on

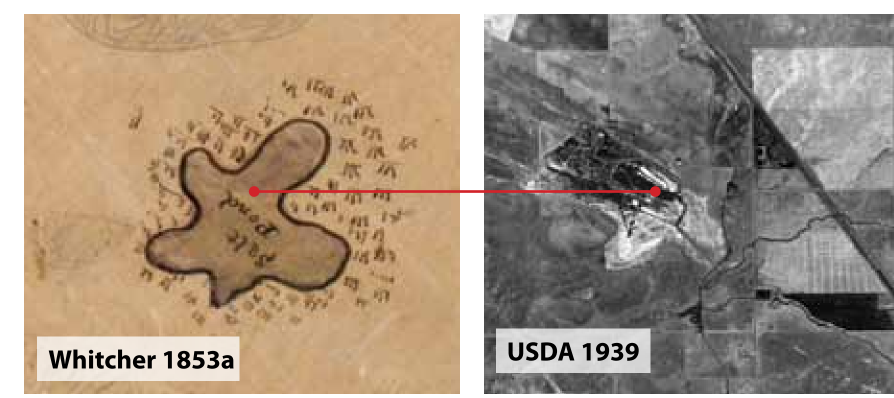
continued on ***page 10***

COMPARISON OF DIFFERENT MAP SOURCES



1 This section of Marsh Creek, at the confluence with Briones Creek, was the site of John Marsh's homestead. The 1853 map depicts Marsh's house, garden, and fence on the edge of Marsh Creek. It also shows a band of trees along Marsh Creek and scattered trees in the surrounding valley. The same pattern is indicated in this 1861 map by Von Schmidt, which shows trees around Marsh's Stone House, completed in 1856. The red dots link the same position on the two images. (See p. 81 for more on this oak savanna.)

2 John Marsh's ranch was called *Los Meganos* ("the sand dunes"), in reference to the sandy soil formation that covered the northern portion of the land grant. Dunes, drawn in 1853 as a speckled pattern, are depicted in the 1918 U.S. Geological Survey quadrangle (Collinsville) as hills of sand up to 120 feet high. Part of this area, just to the east of present-day Antioch, is protected by the U.S. Fish and Wildlife Service as a refuge. (See pp. 90-92 for more details.)



3 A large salt pond surrounded by scrubby vegetation was drawn on the southeastern edge of the land grant boundary. In a 1939 aerial photograph, the same feature—the complex of alkali springs and flats at Byron Hot Springs—is clearly seen from the air. (See p. 54 for a larger comparison of these two images.) In all comparisons, Whitcher 1853a courtesy of The Bancroft Library, UC Berkeley.

HISTORICAL DATA FOR CONTRA COSTA COUNTY

For this project, we collected a wide variety of historical material, including early journals, diaries, and newspaper accounts that describe the ecology of the area; historical maps, surveys, and aerial photos that show where early features were located; and historical landscape photographs, drawings, and paintings that help us understand the historical wetland, dryland, and riparian habitats. Because these sources were produced for a variety of reasons in previous eras, we need to understand who made the maps and for what purpose so that we can evaluate and use the data appropriately. To do this, we also collected information about the surveyors, the agencies they worked for, technical constraints such as scale or mapping methods, and the timing of the document in relation to landscape change. Shown below are examples and brief descriptions of some of the primary sources used in the study. Most of the maps and historical aerial photographs below were placed in physical space and tied to geographical coordinates (georeferenced) in a geographic information system (GIS), as was narrative data that could be accurately located. Examples elsewhere in the report show how multiple sources are used to calibrate our assessment of the historical environment.

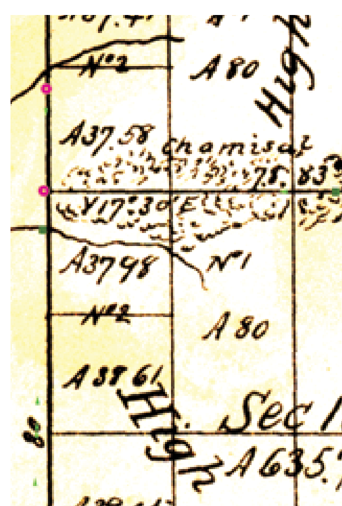
Textual accounts (1772-2011). Written accounts can provide a wealth of detailed information. Spanish expeditions were chronicled in substantial detail, and represent the earliest Euro-American descriptions of the California landscape. Testimony in land grant cases included interviews with local residents and contained details about natural boundaries and features. Surveyors often kept detailed notes about what they mapped. Newspaper accounts add details about early land use history, and major events such as floods or fires that affect the landscape. (Courtesy of the Library of Congress)

An 1899 story titled "Building a Railroad Through a Swamp", in the *San Francisco Morning Call,* describes building "an enormous levee" 12 miles long across the tidal land from Brentwood to Stockton before the tracks were laid for the Sante Fe Railroad.

Mexican land grant sketches (1840s-1850s). As the Mission system disintegrated, influential Mexican citizens submitted claims to the government for land grants. A *diseño*—rough sketch of the property—was included with each claim, and showed distinctive features of the land, such as creeks, wetlands, and woods—often with watercolors, handwritten annotation, and varying systems of symbols and styles. They are some of the earliest maps available of the California landscape. Despite their valuable information, they have been rarely used for environmental research. The detail on the right of Los Vaqueros *diseño*, ca. 1840(b), shows a pond or spring (*Ojo de Agua*) adjacent to Kellogg Creek in the foothills. (courtesy of The Bancroft Library, UC Berkeley)

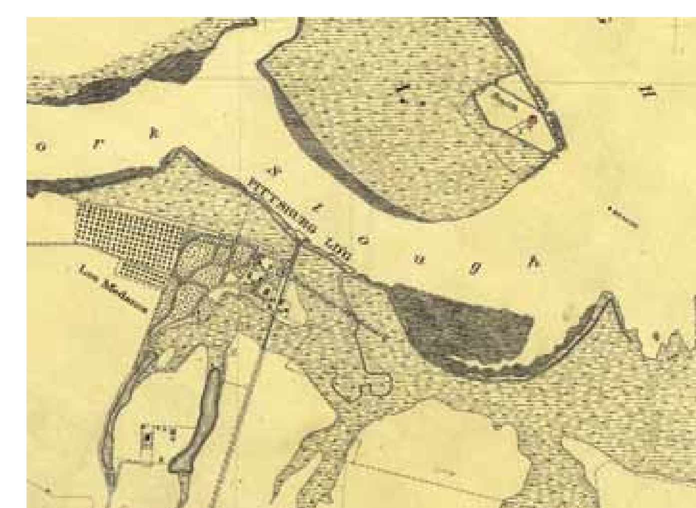
Land grant confirmation maps (1850s-1880s). After the U.S. took control of California in 1848, land grantees were forced to prove the legitimacy of their claims. The claimants had to pay for confirmation surveys performed by civil engineers, under the direction of the U.S. Surveyor General. While the *diseño* was a freehand drawing produced without survey equipment or specialized expertise, confirmation maps were filled with a table of angles and distances in chains. This map of the Rancho Los Medanos was made by J.T. Stratton in 1865(a). While it shows little detail of natural features, it accurately locates the nascent town of Antioch. (courtesy of the BLM)

General Land Office Public Land Surveys (1851-1875). The U.S. Public Land Survey imposed a series of straight lines on the land, dividing property into 6-mile-square townships. Each township was further subdivided into 36 one-mile sections, each section containing 640 acres. Surveyors methodically surveyed section lines with a measuring devise called a Gunter's chain, noting up to four bearing trees at each mile and half mile point, and recording the species and diameter of each tree. They often described natural features such as creek crossings, pools of water, rock formations, and scattered trees. (courtesy of the BLM)

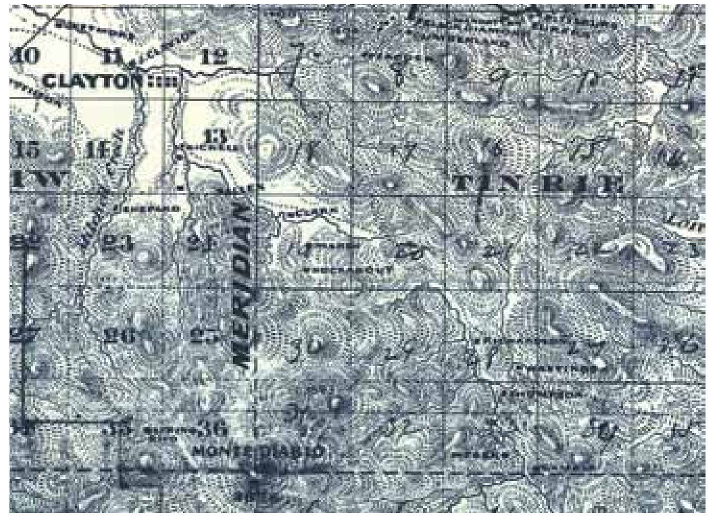


In this plat, surveyor Sherman Day noted in June of 1853, *"The line on this mile passes over a mountain some 1000 or 1200 feet above the valleys below, yellowish, gray sandstone dipping to NE, scattered timber on the sides. Live oak, white oak, buckeye, sycamore, mansanita* [sic] *bushes, and chamisal."*

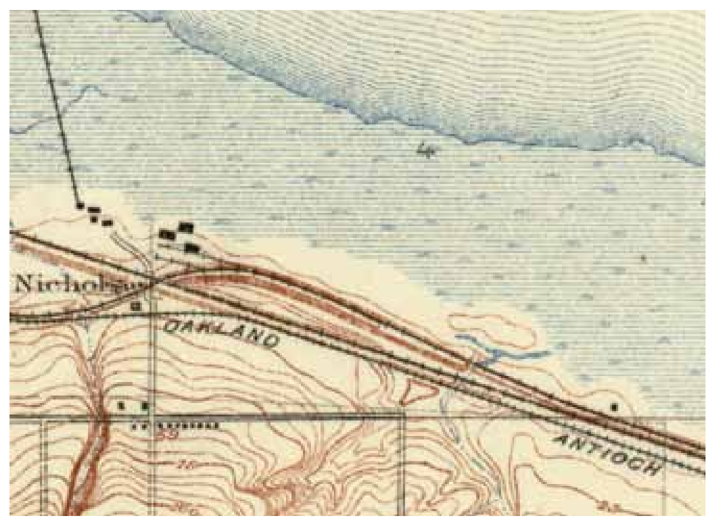
U.S. Coast and Geodetic Survey maps (1866-1887). The U.S. Coast Survey was established in 1807 by Thomas Jefferson to create navigation maps. The large-scale map shown at the right, published in 1887, shows detailed patterns of tidal marsh, sloughs, and tidal ponds just east of present-day Pittsburg. The area is characterized by long tidal ponds reaching inland beyond the tidal marsh, providing a transitional ecotone between tidal marsh and upland grasses. The dark shaded areas on the shore and surrounding nearby Browns Island are depictions of new sediment washed down-river from hydraulic gold mining. These maps are also refereed to as topographic sheets (T-sheets). (Davidson 1887, courtesy of NOAA)



City and county surveys (1870s-1930s). This 1871 county-wide map by Britton and Rey was compiled from the California State Geological Survey, a short-lived but highly regarded state agency that preceded the U.S. Geological Survey. This detail from the map covers the area from Clayton Valley to Mount Diablo, and shows topography, creeks, springs, early roads and trails, township and range section lines, property owners, and some of the Black Diamond coal mines. Large-scale road surveys can also be useful, as they describe features such as creeks or flooded areas. (Courtesy of Contra Costa County Public Works Department)

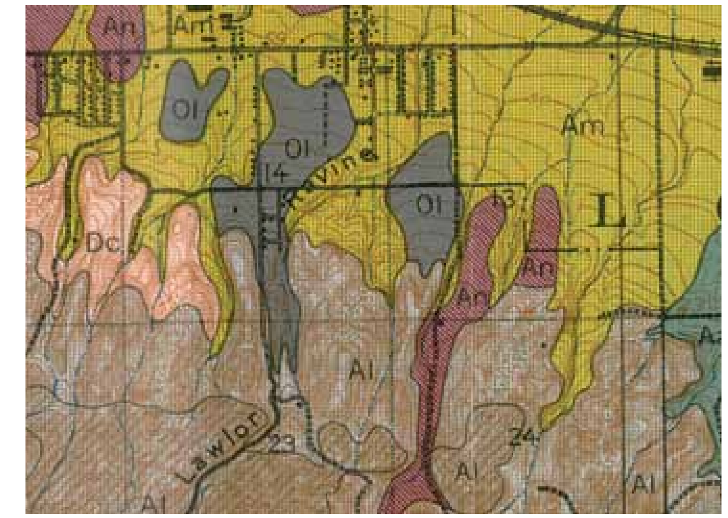


U.S. Geological Survey topographic maps (1896-1970s). The USGS was established in 1879, and until 1900 the largest scale map the agency produced was 1:62,500 (approximately 1 mile to the inch). Shortly after 1900, the USGS started producing maps at twice the scale (1:31,680) for areas of interest. The northern and eastern portions of the study area are covered by these more detailed topographic base maps, with contour intervals of five feet. The area shown here, from the Honker Bay quadrangle (1918), shows detail in the tidal marsh and shoreline along the Suisun Bay.



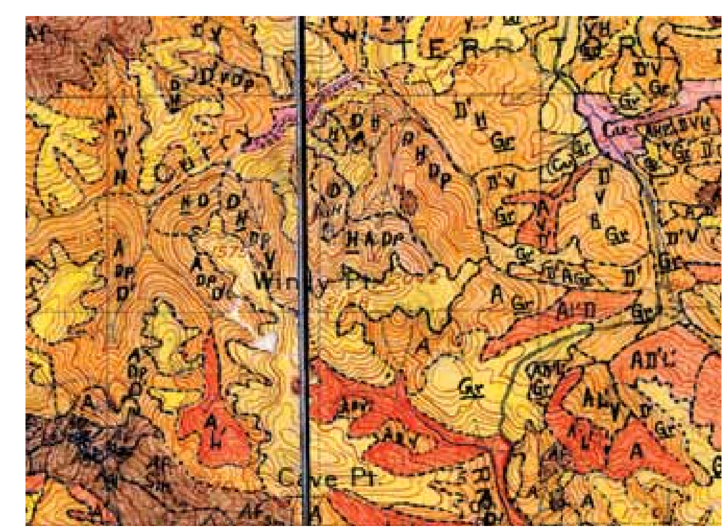
Historical aerial photography (1939). An ambitious Depression-era program to ensure crop stabilization and soil conservation practices resulted in extensive vertical aerial photography for agricultural areas of the country. The images for Contra Costa were taken in 1939 and provide continuous coverage across the project area. While relatively late, the photos nevertheless reveal patterns of historical creeks, alkali wetlands, and woodland, savanna, chaparral, and grassland. Even where agriculture has replaced the natural landscape, trace evidence of natural features often remains, as shown in this image near Byron Hot Springs. (USDA 1939, courtesy of Contra Costa County and Earth Sciences & Map Library, UC Berkeley)

USDA soil surveys (1933-1977). The first U.S. Department of Agriculture soil survey was published in 1899. Early soil surveys were developed to describe the agricultural viability of the soils, but the descriptions can also provide evidence of native vegetation and hydrologic conditions. For example, the Olcott loam soils (Ol) shown on the 1933 soil map to the right by Lawlor Ravine are described as "hard and baked when dry", and "boggy following heavy rains" (Carpenter and Cosby 1939), indicating potential areas of seasonal wetland. These data were used in conjunction with remnant traces on the historical aerial photography to classify wet meadow habitat in this area.



Landscape photography (late 1800s-present). Historical photographs represent a diverse category of historical data that can provide invaluable information not available elsewhere. Research to establish photograph location and land use history makes information gathered from photographs more readily applicable. This early 1930s photograph, part of the Wieslander Vegetation Type mapping documentation, shows the endangered Mount Diablo manzanita *(Arctostaphylos andersonii auriculata)* on a rocky slope just south of Somersville. Coulter *(Pinus coulteri)* and gray pine *(Pinus sabiniana)* can also be seen in the photograph. (courtesy of the Marian Koshland Bioscience and Natural Resources Library, University of California, Berkeley)

Wieslander Vegetation Type Maps (1930s). Maps of California vegetation were developed by Alfred Wieslander for the USDA Forest Service in the 1930s. The maps were created in the field by crews who drew polygons representing vegetation directly on 15-minute USGS quadrangles. They mapped vegetation composition, including the dominant plant species but also less dominant species. We developed a method to adjust the original polygons to historical aerial imagery, thus improving the spatial data while retaining the complexity. Additional detail about this process can be found in the Drylands chapter. This detail from the original quadrangles shows an area near Curry Canyon. (courtesy of ICE, UC Davis)



a Contra Costa County map and more precisely located using both a modern map showing topography and historical aerial imagery showing remnant traces. For the lowlands, we attempted to map features as they would have existed in the mid-1800s, or before large-scale Euro-American modification, which was as early as our data would support. For the upland portion of the study, we relied heavily on 1930s Wieslander vegetation mapping, supported by 1939 aerials, which we believe to be largely representative of earlier conditions. A discussion of how this adjusted Wieslander data represents historical conditions can be found in the Dryland Habitats chapter.

MAPPING METHODOLOGY

A geographic information system (GIS) was used to collect, catalog, analyze, and display the spatial components of our data. 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 step through time by assembling maps and narrative information from different time periods, which allowed us to both assess the different data sources and better understand change.

In the following text we describe how we integrated historical sources into the GIS and then synthesized these sources to produce our habitat map and analyses. We used ArcGIS 9.3.1 (Esri) software.

1) Collection of Historical Spatial Data.

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

2) Addition of Historical Data to the GIS.

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

We developed a continuous historical aerial photomosaic for the study area based upon the earliest available imagery (approximately 230 images, USDA 1939) using the Leica Photogrammetry Suite module of ERDAS Imagine 9.2. Images were orthorectified and mosaicked together to provide county-wide continuous coverage. The photomosaic was particularly useful for identifying wetlands, upland habitats, and former creek alignments within the pre-urban, agricultural setting. Although taken after many significant landscape changes had occurred, these photographs show traces of earlier landscape features that have since been lost. The consistency, accuracy, and high level of detail make these an invaluable source in analysis.

Accurate historical maps with pertinent land cover information were georeferenced to contemporary orthorectified aerial imagery (USDA 2005), using ArcGIS 9.3.1 (Esri). 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 Forests Landscape Ecology Lab at the University of Wisconsin-Madison. The use of these data is discussed further in Chapter 6. Additionally, the GIS was also used to locate and hold textual information gathered from surveyor notes, early explorers' journals, travelers' accounts, and newspaper articles.

3) Synthesis into a Composite Map

We synthesized selected georeferenced historical data into a GIS to create a picture of historical habitat distribution and abundance. Certainty levels were assigned to each feature based upon qualitative or 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, following the standards in Grossinger et al. 2007 (table 2.1, fig. 2.3).

Reliable historical evidence was found for mapping 15 historical habitat or land cover types. These are shown in table 2.2 along with corresponding contemporary wetland and vegetation classes. To record the variations in source data and confidence level associated with different features, we used 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).

Analysis and Comparison to Present-Day Conditions

The recently completed work for the HCP served as our modern comparison data. The HCP identified 25 different land cover types, including wetland, alkali, agriculture, oak savanna, chaparral, and urban. We were able to use this data to track change from historical conditions, and also in some cases as a starting point for our mapping of historical cover.

In our analysis of ECCC we divided the region into geomorphic units based upon those developed by Jones & Stokes (2006) for the HCP (fig. 2.4). The plains region, or plains, includes lands below 200 feet. The foothills fall between 200 and 900 feet. The montane region includes lands above 900 feet. These divisions in elevation correspond to differences in topography as well as social history and land use. We found that these topographically-based units enabled us to summarize regional differences in stream characteristics, vegetation patterns, and human modifications.

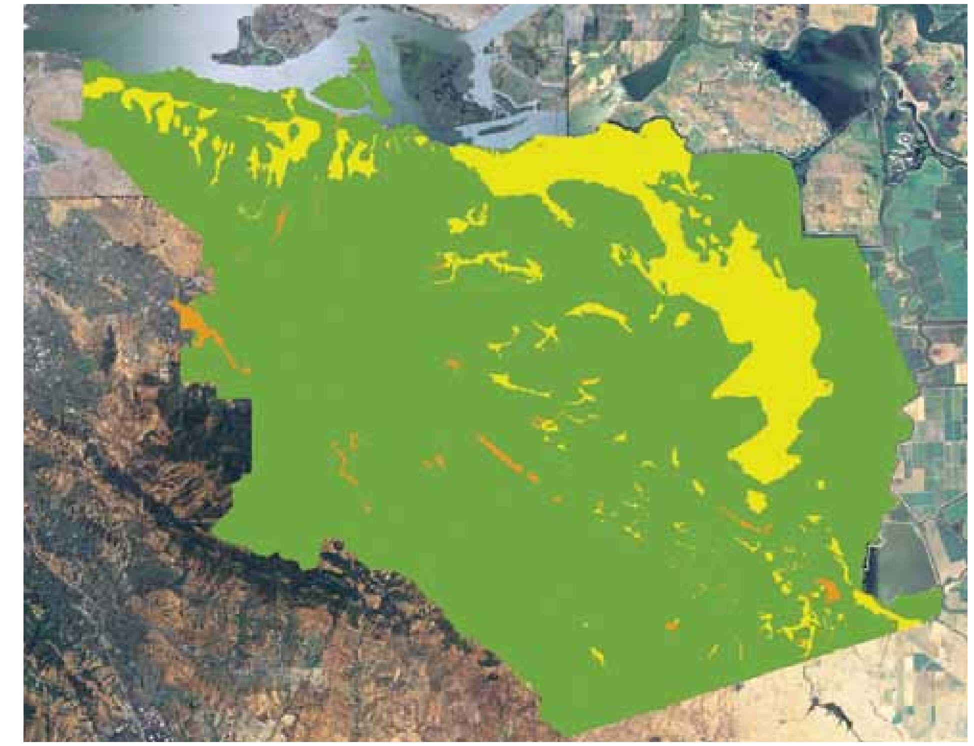


Figure 2.3. Interpretation certainty level for the historical habitat map. Green areas have been assigned a high certainty level; yellow are categorized as having medium certainty level, and orange have been assigned a low certainty level.

Table 2.1 Certainty level standards (after Grossinger et al. 2007).

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)

WHO MAPPED THE SECTION LINES OF EAST CONTRA COSTA COUNTY?

Contra Costa County's earliest existing maps used natural features such as hills, ponds, stream courses, tidal marsh edges, and clusters of trees to indicate land grant boundaries and depict significant landmarks. When California became a state in 1850, the General Land Office (GLO) was charged with developing public land surveys on public domain land, allowing the federal government to more easily distribute property to settlers moving west. GLO surveyors were mandated by the federal Land Ordinance of 1785 to map land using a rectangular township and range system (Carstensen [1976]1985). Surveyors divided land into six-mile square townships with 36 one-mile square sections, parallel to an east-west baseline and a north-south principal meridian, creating a grid of imaginary lines over the state.

The method of surveying was called "chaining the land," because surveyors used a device called a Gunter's chain to measure distances. A Gunter's chain was a steel or iron chain 66 feet long, consisting of 100 links, each 7.92 inches long (Uzes 1977). The chain, a compass, and a transit to measure angles (shown above) were used to methodically walk the section lines of every square mile, except those lands that were designated as land grants. One of the earliest sources of systematic landscape descriptions in East Contra Costa is from the General Land Office (GLO) public land surveys, which started in the county in 1851.

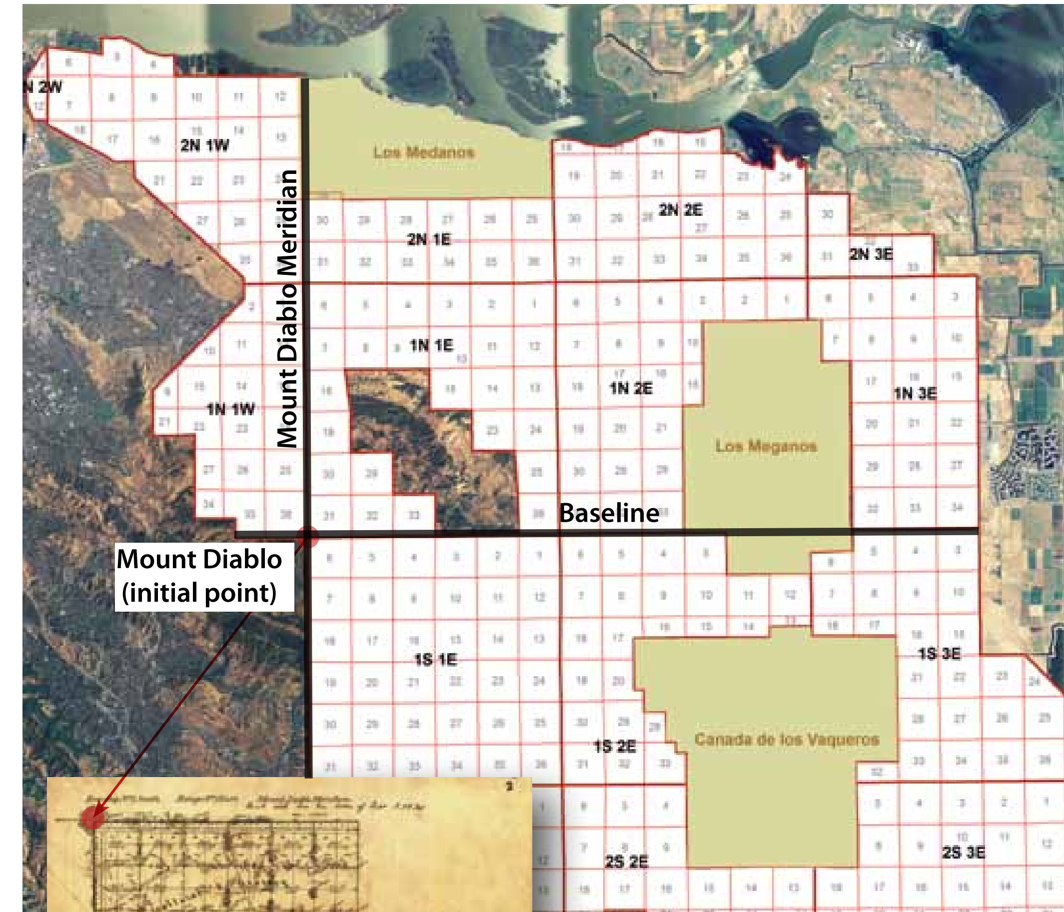
Until 1910, the public land surveys were carried out by deputy surveyors who contracted with the federal government, and the survey teams were paid between $2 and $8 a mile. Deputy surveyors often held additional jobs or owned a farm or ranch of their own (Clement [1958]1985). Some were significant figures in regional surveying and engineering. Surveyors were instructed to record information about the land they were passing through, including the nature of the soil, minerals, trees and timber, tidal lands, creeks, springs, and alkaline ponds. Some surveyors used their experience and later became land agents, or purchased large tracts of land themselves. An understanding of the individual surveyor helped us to interpret the GLO data, as some surveyors were highly observant, and created detailed and descriptive field notes, while others recorded more limited inventories (Johnson 1976).

Following are descriptions of some early surveyors who mapped East Contra Costa.

LEANDER RANSOM (1800-1874) came to California in 1851 with Samuel King, the U.S. Surveyor General, and was charged with establishing an "initial point" for the primary principal meridian and baseline for California's GLO survey (fig. 2.5). In July, 1851, Ransom and his survey crew traveled with pack animals loaded with survey equipment to the top of Mount Diablo, but found the terrain so rugged that they needed to create a series of offset lines below the peak to establish the initial point (White 1991). Ransom later served as Chief Clerk in the California Surveyor's General office in San Francisco (Pettley [2000]).

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 Nevada were both named after Day. To the right, Day is pictured with survey equipment in front of an Almaden Mine tunnel in a 1880s photograph by Carleton E. Watkins.

E.H. DYER (1822-1906) surveyed East Contra Costa for the GLO between 1861 and 1869. Dyer was born in Maine, and joined his brother in California in 1857. He later saw an economic opportunity in sugar beets and established the first successful mill in California. He owned several lots along Alameda Creek near Alvarado (present-day Union City).



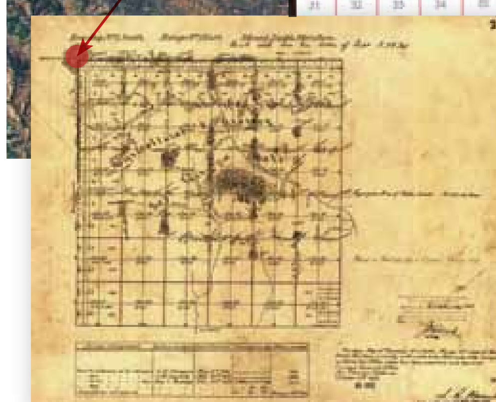


Figure 2.5. The township and range grid in East Contra Costa (above) was established by the GLO after Leander Ransom surveyed the initial point at Mount Diablo. Land grant boundaries are shown in light green. Deputy surveyors walked each section line, taking an inventory of natural features and establishing property boundaries using a chain to measure the land. A compiled GLO survey of Township 1 South, Range 1 East (the first township south and east of the initial point of Mount Diablo) is shown tied to the peak at Mount Diablo. The open area just north and east of the peak was so rugged that the land was never surveyed, and provisional lines are shown on contemporary US Geological Survey quadrangles. (map courtesy of the Bureau of Land Management; photo courtesy of The Bancroft Library, UC Berkeley)

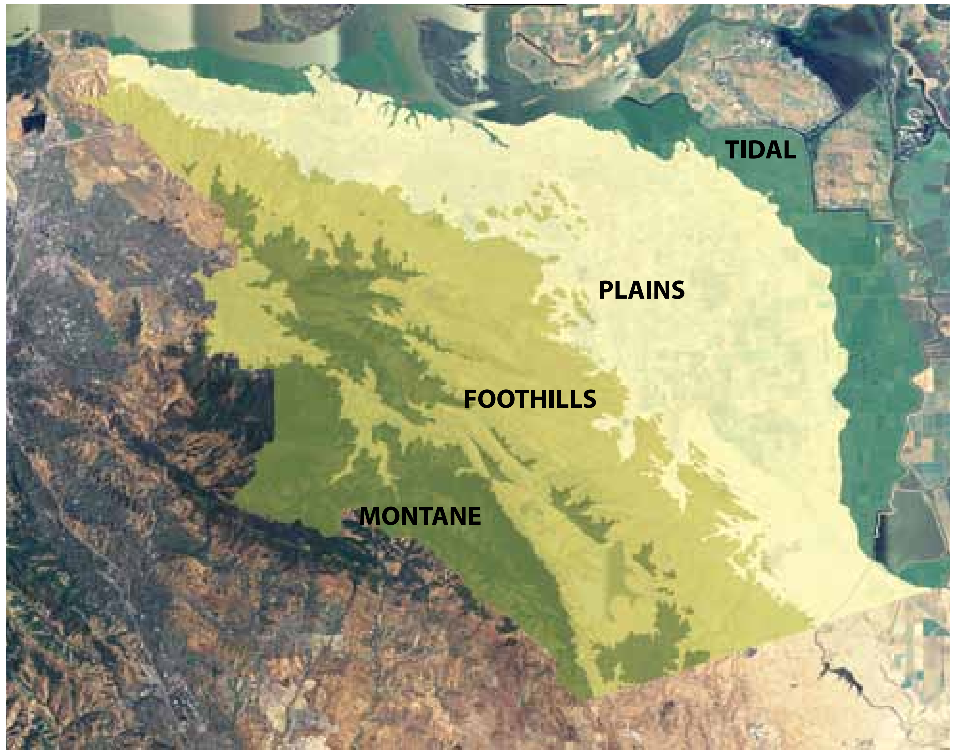


Figure 2.4. Geomorphic units for ECCC. Geomorphic units are montane, (>900 ft), foothills (200-900 ft), plains (<200 ft), and tidal.

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 Committee provided comments on the draft report; several advisors also provided guidance and review on specific topics during the course of the project.

Members of the Contra Costa Watershed Forum, the Friends of Marsh Creek Watershed, and Contra Costa County staff provided comment and advice through local presentations and project meetings.

Both the historical habitat map and the orthorectified historical aerial mosaic are available to the public. The habitat map and report can be downloaded at www.sfei.org/HEEastContraCosta.

Table 2.2. Habitat crosswalk. Crosswalk between historical land cover types used in this report and contemporary classification systems, including the HCP landcover types. The MCV types listed represent a sampling of the contemporary habitat types that could crosswalk with the historical types – the list is not exhaustive.

Habitat Type	Wetland Classification and Water Regime (Cowardin 1979)	Vegetation Classification (NDDB: Holland 1986; MCVII/CNDDB: Sawyer et al. 2009)	HCP/NCCP (Jones & Stokes 2006)
Tidal Marsh	Estuarine intertidal persistent emergent wetland. Regularly flooded, permanently saturated.	Coastal brackish marsh (NDDB), Coastal and Valley Freshwater Marsh (NDDB), American/Hardstem/California bulrush marsh (MCVII)	
Wet Meadow	Palustrine emergent wetland. Temporarily flooded, seasonally to permanently saturated.	Native grassland (NDDB), Valley wildrye grassland (NDDB), Creeping rye grass turfs (MCVII)	Seasonal Wetland, Grassland
Valley Freshwater Marsh	Palustrine persistent emergent freshwater/saline wetland. Temporarily to permanently flooded, permanently saturated.	Coastal and valley freshwater marsh (NDDB), California bulrush marsh (MCVII), Cattail marshes (MCVII)	Permanent Wetland
Perennial Freshwater Pond	Permanently flooded.		Pond
Alkali Meadow	Palustrine emergent saline wetland. Temporarily flooded, seasonally to permanently saturated.	Alkali meadow (NDDB), Alkali seep (NDDB), Alkali weed - salt grass playas and sinks (MCVII), Salt grass flats (MCVII), Creeping rye grass turfs (MCVII), Alkali heath marsh (MCVII)	Alkali Grassland, Alkali Wetland
Alkali (Valley) Sink Scrub	Palustrine emergent saline wetland. Temporarily flooded, seasonally to permanently saturated.	Valley sink scrub (NDDB), Iodine bush scrub (MCVII)	Alkali Grassland, Alkali Wetland
Alkali Flat	Seasonally flooded, temporarily to seasonally saturated.	Alkali playa (NDDB), Alkali weed-salt grass playas and sinks (MCVII), Salt grass flats (MCVII)	Alkali Wetland
Alkali Marsh	Palustrine persistent emergent freshwater/saline wetland. Temporarily to permanently flooded, permanently saturated.	Cismontane alkali marsh (NDDB)	Alkali Wetland
Perennial Alkali Pond	Permanently flooded.		Pond
Grassland		Native grassland (NDDB), Purple needle grass grassland (MCVII), Curly blue grass grassland (MCVII)	Grassland (Native Grassland)
Oak Savanna		Valley oak woodland (NDDB), Blue oak woodland (MCVII), Valley oak woodland (MCVII)	Oak Savannah
Woodland		Valley oak woodland (NDDB), Blue oak woodland (MCVII), Valley oak woodland (MCVII)	Oak Woodland, Mixed Evergreen Forest
Chaparral		Coastal sage chaparral scrub (Holland), Chamise chaparral (MCVII), Scrub oak-chamise chaparral (MCVII)	Chaparral and Scrub
Interior Dune Scrub		Interior stabilized dune (NDDB), Scrub oak chaparral (NDDB), Live oak chaparral (MCVII)	
Interior Dune (vegetation undefined)		Interior stabilized dune (NDDB), Scrub oak chaparral (NDDB), Live oak chaparral (MCVII), Live oak woodland (MCVII)	Oak Savannah, Grassland

CHAPTER 3

LAND USE AND CLIMATE HISTORY

Farther than the eye can reach to the eastward and southward, extending from Bay Point to Byron, lie the eighty thousand acres of wheat field, level almost as the floor, from which come the great quantities of grain shipped annually from Antioch.

—CONTRA COSTA COUNTY 1887

LAND USE

This section reconstructs general patterns of land use in East Contra Costa County (ECCC) over the past 200 years (fig. 3.1). Understanding major prehistorical and historical land use trends is essential to understanding native habitat patterns. In this section, we give a brief overview of major land use trends.

First Human Settlement

The story of the indigenous people of East Contra Costa County is told in large part through the vast record of the human experience of colonization – as detailed by the colonizers themselves. The tribes of the area had no written language prior to the arrival of the Spanish in 1769, so Spanish writings provide our first narrative glimpse of the region's people. There is also a robust physical record of human life in the region which lies in archaeological contexts – and the living descendants of the tribal people have memories, records, and family histories that detail the indigenous experience in ECCC. What we now know of the immediate, post-colonial story of these people – which captures the most recent, prehistoric arrangement of human civilizations in the region – comes primarily from the work of one individual, Dr. Randall Milliken. Together with local tribal and professional colleagues, Dr. Milliken has spent much of the last 30 years building on past work of Harrington, Merriam, Bennyhoff, and others to piece together the human experiences of colonization in the Bay Area (see Milliken et al. 2009).

Another perspective on pre-colonial life in ECCC can be derived from an examination of subsistence lifeways and patterns of natural resource management practiced by local tribes. Indian fire management, large-scale harvest and manipulation of terrestrial and aquatic floral and faunal resources had, at times, profound influences on the function and resilience of ecosystems throughout the region.

Archaeological records of human presence in ECCC stretch back thousands of years. Archaeologists have found traces of human activity dating to nearly 10,000 years ago near the Los Vaqueros Reservoir (Ziesing et al. 1997), and to at least 6,000 years ago near Marsh Creek (Rosenthal et al. 2006). A later site at Los

Figure 3.1. Land use in East Contra Costa County. Top row of images, left to right: A) an early highway crosses an extension of Kellogg Creek, ca. 1920; B) a barge loaded with cargo at the Antioch wharf; C) intensively farmed crops east of Marsh Creek have almost entirely replaced native vegetation by 1939. D) This early 20th century oblique view shows grain and scattered oaks in the valley now flooded by Los Vaqueros Reservoir. (A: Unknown ca. 1920, courtesy East Contra Costa Historical Society; B: Unknown ca. 1900b, courtesy Society of California Pioneers; C: USDA 1939, courtesy Contra Costa County and Earth Sciences & Map Library, UC Berkeley; D: Unknown ca. 1920, courtesy of the California Historical Society)

Vaqueros Reservoir revealed traces of residences including hearths and hunting tools dating to between 3,000 and 1,500 years ago (Ziesing et al. 1997). Dr. Milliken estimates that population density in the Bay Area at the time of contact ranged from two to six people per square mile, high for a nonagricultural society (Milliken 1995). The largest Bay Area village recorded by early explorers was within Contra Costa near Carquinez Strait, and contained an estimated 400 people (Anza 1776 in Brown 1998:59-63, Milliken 1995).

At the time of Spanish contact in 1772, ECCC was home to several small tribes representing the Delta Yokuts, Ohlone/Costanoan, and Bay Miwok language groups (Bennyhoff 1977, Milliken 1995). Table 3.1 provides a basic overview of the geographic, linguistic (e.g., Bay Miwok), and tribal (e.g., Chupcan) associations in ECCC. All of these groups shared similar world views, political organizations, and hunting and gathering material cultures, but each also had a unique language, a unique history, and a special relationship with a specific portion of what is now ECCC (fig. 3.2).

Native people in California did not practice agriculture as it is typically described; however they did modify the landscape in a variety of important ways (Lewis 1985, Stewart et al. 2002, Anderson 2005, Martinez 2010 in prep). Tribal groups managed lands under their influence with practices such as seed beating, scrub and grassland burning, harvest of grasses, and use of digging sticks to turn the soil (see Anderson 2005). Products harvested by Native groups included acorns, grasses and forbs, intertidal and nearshore marine products, and tule to construct rafts and innumerable other products (Kroeber [1925] 1976). Archaeological research reveals that a high diversity of shellfish, large and small mammals, birds, and small fishes were eaten by native people living near Marsh Creek in the middle Holocene (Rosenthal et al. 2006). Native groups also hunted game such as deer, pronghorn antelope, and elk, which appeared to be abundant in ECCC at the time of Spanish contact (Anza 1772 in Brown 1998, Font and Bolton 1933).

Of particular interest to land managers as well as tribes today is the historical use of fire by local tribes to maintain and enhance resilience of local ecosystems. Native groups used fire to control the distribution of chaparral, maintain grassland cover and forage for wildlife, control pathogens, improve access to acorns, and aid in hunting rabbits and other small game (Kroeber [1925] 1976, Keeley 2002, Stewart et al. 2002, Anderson 2005). While indigenous fire use specifically in ECCC is not well documented, observations by early explorers, and subsequent observations of changes in terrestrial vegetation in response to fire suppression indicate that ECCC was managed with fire much as other, similarly populated areas.

Recent quantitative studies of fire ecology and fire behavior (e.g., Stephens and Fry 2005, Evett et al. 2007) have concluded that local tribes were the source of a high majority of all fire ignitions in many coastal regions prior to colonization. Historical incidents of lightening cannot explain the frequency of historic fires in these areas as recorded by fire scarred tree records and other proxies. Over the millennia, shifting patterns of managed burns created a rich mosaic of habitats, likely increased edge area, and created more resilient ecosystems (Martinez 2010 in prep; see Dryland Habitats, chapter six). However, quantitative models of the impact, distribution, and frequency of managed fires at a localized scale are only starting to receive funding for study (e.g., Johnson et al. 2010). Concurrently, new and existing technologies are being brought to bear to answer growing questions about how Native fire management may inform contemporary management of terrestrial vegetation management, ecological restoration, and conservation of threatened species.

Table 3.1. Geographic, linguistic, and tribal associations in East Contra Costa County.

Geographic Region	Tribe/linguistic group
Pittsburg	Chupcan Bay Miwok
Antioch	Julpun Bay Miwok
Brentwood	Jalalon Delta Yokuts
Byron	Tamcan Delta Yokuts
Mount Diablo/Briones Valley	Volvon Bay Miwok
Morgan Territory	Ssouyen Ohlone
Brushy Creek	Ssaoam Ohlone

Figure 3.2. Sacred sites. East Contra Costa County contained important spiritual sites for native peoples, which were featured in local legends. Pictured here are (A) Mount Diablo, (B) Byron Hot Springs with Clift Court forebay, (C) Brushy Peak (in Alameda County, but important to ECCC tribes), and (D) Vasco Caves. (Top left image by Scott Hein, www.heinphoto.com; all other images by Abigail Fateman, Contra Costa County)

[Moving east towards Antioch] *On coming down from this gap, we hit upon a large plain and followed it in an easterly direction, seeing upon it a great many antelope, deer, geese, cranes, and no few tracks of the buffalo or mule-deer, and another trace like a mule's... The soil appeared good and rather grassy but scarce in wood.*

—Fages 1772 in Stanger and Brown 1969

Spanish Contact (1772-1835)

The first Spanish exploration of ECCC took place in 1772, in an expedition led by Don Pedro Fages. The explorers moved east through northern Contra Costa and turned around just beyond Pittsburg (Crespí and Bolton 1927, Cook 1957). In 1776 a second expedition, led by Juan Bautista de Anza, continued further east along this route and were turned back at the edge of the extensive Delta marshes (Bolton et al. 1930, Cook 1957).

After missions San Francisco de Asís (Dolores) and San José were founded in 1776 and 1797, the Spanish presence began to more directly impact the native population (Milliken 1995). Based on mission baptism records, researchers believe that missionization of native tribes generally moved outward from the missions, reaching more distant tribes after those closest to the mission had already been converted or had moved off of the land. In 1805 and 1806, mission records list baptisms of Volvon, who lived in the uplands near Mount Diablo and along Marsh Creek (Milliken 1995), and by 1806 this group had essentially been removed from ECCC (Praetzellis et al. 1991). The reach of the missions continued eastward until by 1812 ECCC was almost entirely uninhabited (Milliken 1986 in Praetzellis et al. 1991).

Throughout the mission period, ECCC indigenous peoples moved from mission to mission and mission to rancho/pueblo,. They also intermarried, sometimes with traditional allies, yet often far outside their cultural kin – even outside the Native community. New, mission-based identities evolved, often reflecting a blending of cultural expressions, though many families retained ties to their historic lands. The missions were secularized in 1835-1836, and their landholdings were gradually broken up. With the collapse of the Mission system, the much reduced Native populations were denied the land that had been promised them and were left to either work for Spanish landowners or move to uninhabited lands further east (Milliken 1997b, Ziesing et al. 1997). Many returned to their original villages, but some may have settled regions that were historically occupied by other tribes (Davis et al. 1997). Children were often relegated to legalized slavery, moved en masse to boarding schools, and prevented from speaking their languages and practicing their cultures. Today, the descendants of these indigenous groups are represented through one or more organized tribal governments (Milliken et al. 2009).

Rancho Period (1835-1848)

After the dissolution of the missions, the Mexican government granted land to private individuals for stock-raising and agriculture. In 1835, the first ECCC land grant deeded Los Meganos to Jose Noriega (fig. 3.3), who in turn passed the grant

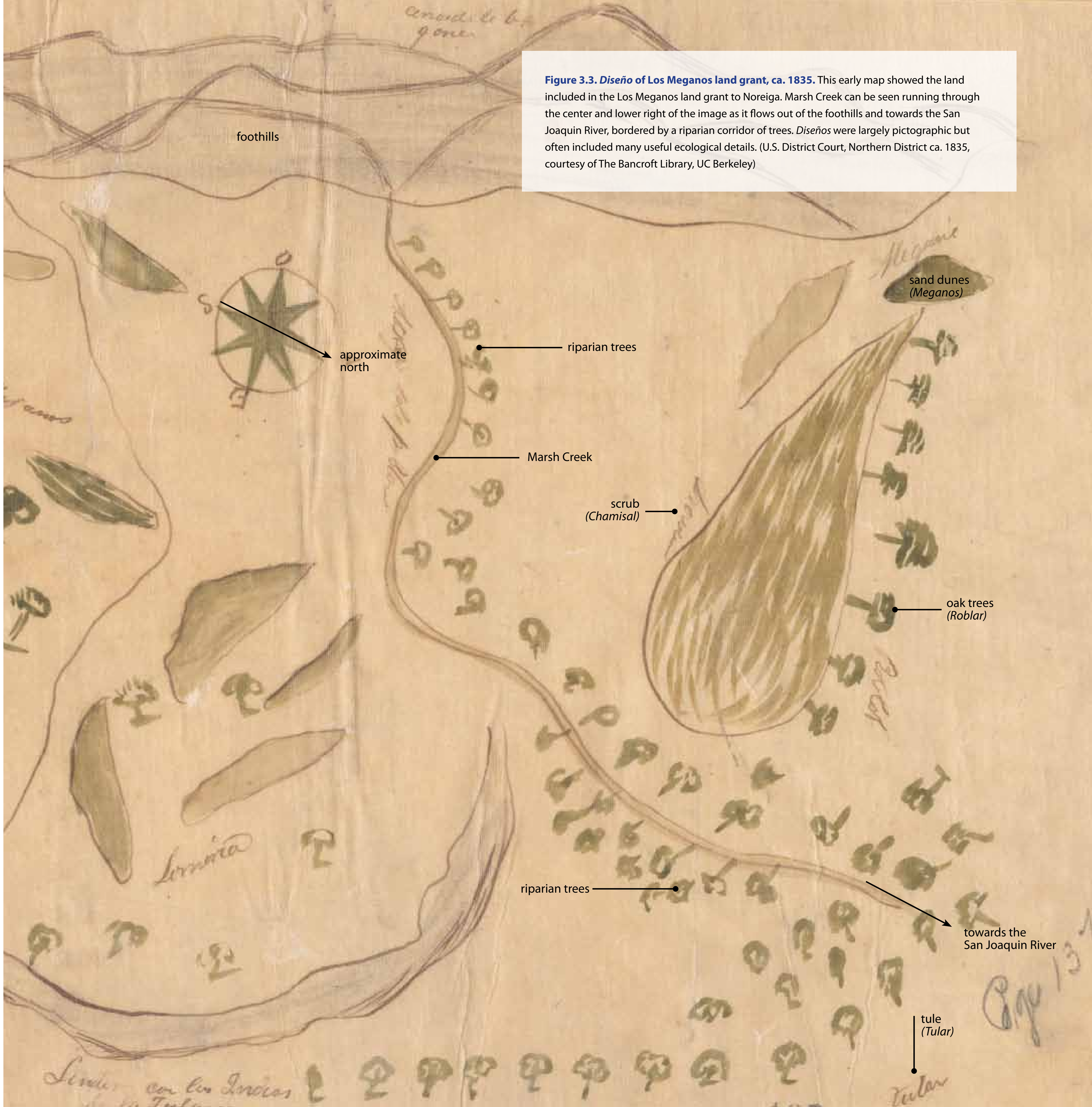


Figure 3.3. *Diseño* of Los Meganos land grant, ca. 1835. This early map showed the land included in the Los Meganos land grant to Noreiga. Marsh Creek can be seen running through the center and lower right of the image as it flows out of the foothills and towards the San Joaquin River, bordered by a riparian corridor of trees. *Diseños* were largely pictographic but often included many useful ecological details. (U.S. District Court, Northern District ca. 1835, courtesy of The Bancroft Library, UC Berkeley)

to American John Marsh. Additional land grants were made in 1839 (Los Medanos) and 1844 (Los Vaqueros). The land grants, and especially the arrival of John Marsh, signaled the beginning of Euro-American habitation in ECCC. Prior to Marsh's arrival, Mexican families in the region had avoided living in inland areas because they were subject to raids by native peoples or attack by grizzly bear (Miranda 1880, Milliken 1997b). Marsh chose to live in the region to ranch cattle and began encouraging other settlers to join him. Native people (likely Julpunes and/or Volvons) who had returned to the area from Mission San José lived along Marsh Creek and helped to work Marsh's land (Milliken 1997b).

Until this time, European impact on the land had been relatively limited. Mission San José may have used portions of ECCC for grazing cattle during the early 1800s, but these cattle grazed primarily in the Livermore Valley and only occasionally reached north to Contra Costa near Los Vaqueros or up San Ramon Valley to Clayton (Bowman 1947). As the settler populations began to increase, their impact on the natural environment became more pronounced, although there was little cultivation through the rancho period.

These early ranchers allowed cattle to run freely over their land, and unclaimed public land was used for communal grazing (Alviso 1853, Welch 1880). The grazing may have helped spread non-native grasses, as well as limiting opportunities for forest regeneration (Swiecki and Bernhardt 1993). By some accounts, ECCC was overgrazed by the 1850s, to the point that ranchers slaughtered wild horses to relieve grazing pressure on the grasslands (Purcell 1940). Landowner Ignacio Sibrian (1881) described conditions in the 1850s:

> Q. Did not the cattle of the whole neighborhood graze upon and feed upon the rancho before it was fenced by Perez?
>
> A. The hills was public, everybody's cattle, mine, Pacheco's and everybody's cattle run on the ranch….Until 1862, everybody's cattle run there, they did not use to go and brand them, they were not worth branding.

Early American Settlement and Agriculture (1848-1930s)

After California became part of the United States in 1848, settlement intensified and plots became smaller. To retain their lands under the American government, owners of the Los Vaqueros, Los Medanos, and Los Meganos grants had to prove their claims, a process that produced land case testimony and associated confirmation maps. Although all three land grants were ultimately approved, they were divided into smaller holdings through this process, opening the way for more settlers.

The new settlers became squatters within land grants, or claimed the land remaining outside of land grant boundaries (Pacheco 1861). They raised sheep and cattle, as the Mexican landowners had done, but these cattle were primarily for dairy and beef rather than for hides (fig. 3.4). The arrival of new American settlers accelerated a movement towards grain, which lent itself more readily to small plots and required less investment than cattle.

Over the second half of the 19th century, ECCC transitioned from primarily ranchland to grain production. The first crop of grain was planted by John Marsh in 1839 (Lyman 1931); by 1892 the California Department of Agriculture stated that "nearly half of this [Contra Costa County] is cultivated, the remainder being grazing and waste land." As in much of California, the flood of 1862 followed by the drought in 1863 and 1864 killed large numbers of cattle and helped to speed the transition to grain cultivation (History of Contra Costa County 1882, Purcell 1940). The rise of grain was marked by increased use of fences, and in 1872 a law was finally passed which shifted the responsibility for constructing fences to protect crops from livestock to ranchers rather than farmers (Praetzellis et al. 1997). Even the heavily grazed Los Vaqueros land grant had been converted to dry-farmed grain by 1880 (Ziesing et al. 1997; fig. 3.5).

Wheat was the most dominant cultivated crop in Contra Costa at this time (Smith and Elliott 1879), although dry-farmed alfalfa for cattle was widely grown in the eastern portion of the county (Taylor 1912a). Many early accounts boasted that alfalfa could grow without irrigation because of the high groundwater level in the east near the San Joaquin River (Douglas 1908, *Contra Costa Gazette* 1912). Alfalfa could also tolerate low levels of alkali: "alfalfa will grow in soil containing an appreciable accumulation [of alkali] if the salts are below the feeding zone of the plant roots during the seedling stage" (Carpenter and Cosby 1939). Farmers dry-farmed alfalfa well into the 20th century.

Grain farming also extended up the foothills, as "the hills dividing these valleys are no less valuable or productive than the valleys" (Contra Costa County 1887, Adams pers. comm.). The *Antioch Ledger* reported on this transformation in 1872(b):

> Five years ago the plains between Antioch and Bay Point to the westward, and to Banta's [near Tracy] to the east and south, presented to the eye one vast area of grazing land. Flocks and herds roamed at large…Today nearly every acre of the entire scope of country between the points named is sown to wheat.

As more settlers began to move into the area, they also harvested wood. Settlers cleared trees for use as fuel or fence posts (Gehringer n.d.; History of Contra Costa County 1882; *Byron Times* 1908a, b; Carpenter and Cosby 1939; Homan 2001). Ranchers also thinned small, easily cleared trees in the upland woodlands to improve grazing for their cattle (Engelhart pers. comm.). However, trees were not appropriate for lumber: narrative accounts described trees "of little practical value" (History of Contra Costa County 1882), or bemoaned that among the "shrubby white oaks, there was not one tall enough to make a rail-cut" (Bidwell [1842] 1937).

Figure 3.4. Sheep near Byron. This postcard, labeled "Greetings from Byron" shows sheep grazing under oak trees, presumably in the hills south and west of Byron. Sheep were able to withstand the xeric climate better than cattle. (Unknown n.d., courtesy of the East Contra Costa Historical Society)

Live oak wood for sale. Near the public road, 3 miles north of Brentwood. Good Road. Price, $7.50 per cord. The wood is opposite the Siple place. James O'Hara, Oakley.

—*BYRON TIMES* JULY 31, 1908A, NEAR THE INTERIOR DUNE SCRUB OAKS AT OAKLEY

Wood for sale! 100 cords of stove wood and lot of bark, all corded, will be sold for $5 a cord for the wood and $2 a cord for the bark, in lots of 10 to 20 cords. Bark will make splendid summer fuel. The wood is on the Heidorn place, near Knightsen.

—*BYRON TIMES* JULY 17, 1908B, NEAR THE OAK SAVANNA AT POINT OF TIMBER

It is a very finely located piece of land, devoted mostly to wheat, but has a fine young orchard of most varieties of fruits. A mountain stream, called Kellogg Creek, passes on the south side of the farm, and its waters are used when necessary for irrigating purposes. There are on the farm at least twenty-five of those grand old oak trees, whose boughs gracefully sweep down and reach the ground. These oaks have a great resemblance to the weeping willow or elm of the East. The fields look like an old park, as the trees are low branched, wide-spreading, gnarled; they are magnificent in size; many of them must be hundreds of years old; they are disposed about the plain in most lovely groups, masses or single ones.

—Smith and Elliott 1879, "Canadian" (Volney) farm - accompanying illustration at right

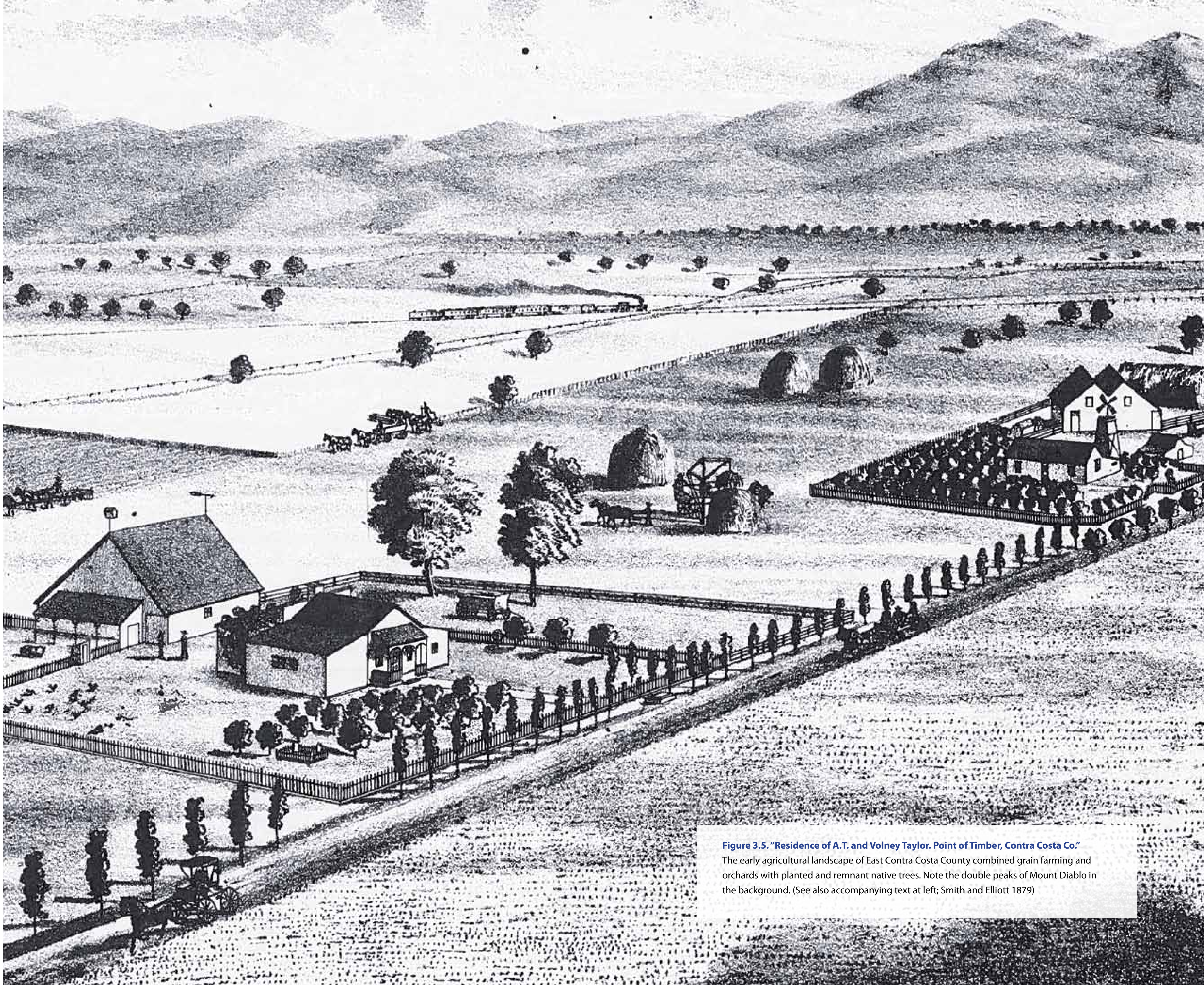


Figure 3.5. "Residence of A.T. and Volney Taylor. Point of Timber, Contra Costa Co." The early agricultural landscape of East Contra Costa County combined grain farming and orchards with planted and remnant native trees. Note the double peaks of Mount Diablo in the background. (See also accompanying text at left; Smith and Elliott 1879)

Industrial Development and Mining (1853 - present)

In 1853 Antioch opened a wharf, the furthest inland wharf in the region, and the beginning of ECCC's industrial development. Through the late 19th century and early 20th century, factories developed along the San Joaquin River that produced lumber, paper, pottery, and glass. Mining operations extracted coal, silica, cinnabar, silver, gold, and even petroleum from the foothills (see Davis and Vernon 1951). Tule gathered near Antioch was shipped to San Francisco to construct products such as mattresses, upholstery, and paper *(Antioch Ledger*1872a, *Pacific Rural Press* 1875, Benyo 1972*)*. By 1877 the Central Pacific had run a railroad through Contra Costa, linking it with the rest of the region.

The first and most intensively mined substance was coal, with production beginning in the 1860s and continuing until 1902 (Davis and Goldman 1958). A series of 12 coal mines were developed in the foothills north of Mount Diablo, the largest of which was Black Diamond Mine. At the mines' production peak in 1874, they produced over 480 million pounds of coal per year, and employed 1,000 miners, spurring a wave of settlement in ECCC foothill towns such as Nortonville and Somersville (fig. 3.6, 3.7). The first railroad in ECCC was built to ship coal to the wharves, and was completed by the mid-1860s. Mining declined in the late 1870s due to decreasing profits and competition from superior imported coal, and by the 1880s mines were beginning to close. Some miners left for newly developing mines in what is now Washington State, while others remained as settlers in Contra Costa.

Early industry impacted local hydrology and ecology in many ways. Silica mining in the Antioch dunes reduced their height from an original 65-115 feet down to 50-80 feet by 1957 (Davis and Goldman 1958, Howard and Arnold 1980). Clay kilns in Antioch were fired with oak wood harvested from the savanna in Clayton Valley (Gehringer n.d.). Gravel to build local roads was mined from Marsh Creek (Hohlmayer 1996; fig. 3.8). Mining for coal and other minerals disturbed hillsides and displaced soil and vegetation, contributing to erosion and stream incision. Mining tended to concentrate in the relatively untouched foothill and montane regions, which had been less impacted by agriculture than the plains. Mining also led to a rapid increase in population, as immigrants moved to the mines and then spread across central and eastern Contra Costa.

Mines also produced debris and contaminants. The plaintiff in an 1881 court case complained that "screeings, ashes, and other substances" were washed down Kirker Creek from Black Diamond Mine and decreased the value of the downstream property (*Robinson v. Black Diamond Coal Company* 1881). A mercury mine operated intensively from 1875-1877 and intermittently thereafter has continued to leach mercury into the Marsh Creek watershed (Davis and Vernon 1951, Cain et al. 2004, Jones & Stokes 2006), and is still visible at the intersection of Marsh Creek Road and Morgan Territory Road.

The tule factory near Antioch is now in active operation. One shipment of prepared tule has been already forwarded to San Francisco, and the proprietors are desirous of contracting for the cutting and delivery at the factory of a sufficient quantity of tule to supply the winter trade.

—*PACIFIC RURAL PRESS* NOVEMBER 6, 1875

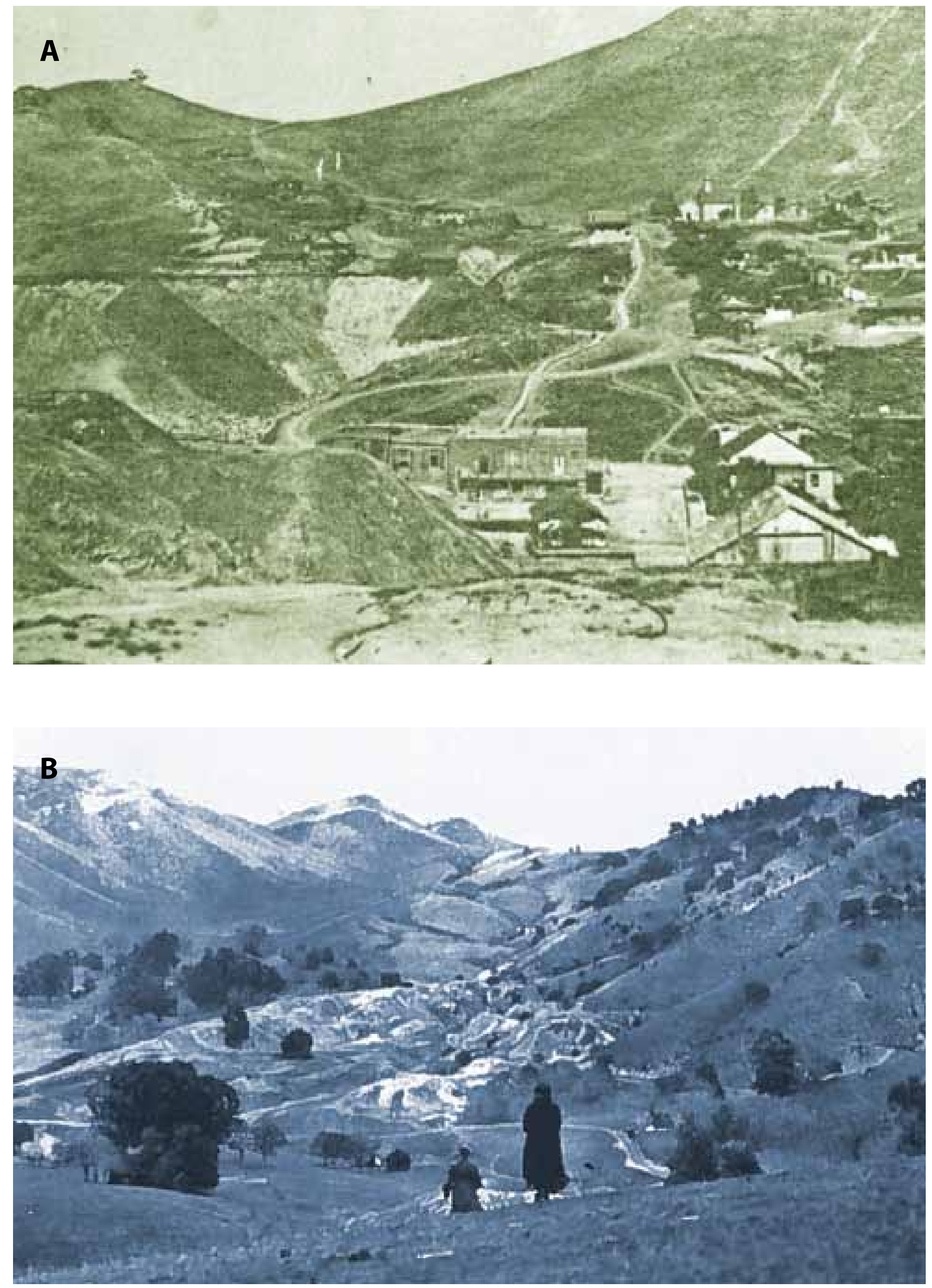


Figure 3.6. Coal mining. A) Coal mining at Nortonville. The Black Diamond Mine waste rock deposits are visible at bottom left. B) Somersville townshite - mining debris is still visible in the waste rock pile at center of this image. (A: Unknown ca. 1870, courtesy of the Pittsburg Historical Society; B: Unknown 1924, courtesy of East Bay Regional Park District)

Figure 3.7. Coal mining sites. The mining towns of Nortonville, Somersville, Stewartsville, and West Harley are shown here with the railroads that connected them to the Sacramento-San Joaquin River.

Another parts [sic] *of it is used for depositing coal for shipping. Some of New York and some of Antioch-At these places they ship the coal from the natural ground without any wharehouses* [sic] *and it frequently lies there from eight to ten days accumulating to two or three hundred tons of coal which if the tides was to wet it the salt would destroy the value of the coal.*

—JOHN CLAYTON 1865

One of the most promising mineral locations in Contra Costa is the quicksilver mine near the eastern base of the main summit of Mount Diablo. This mine has been known to the Indians from time immemorial. A very aged Indian, who has given up the roving habits of his race, and "located" in the vicinity of this mine, says that from the time of his boyhood all the Indians in that region have been in the habit of resorting to that place for obtaining the red paint (sulphate of mercury) with which they were accustomed to bedaub themselves on all occasions of great festivity or when preparing for battle.

—UNKNOWN 1865, QUICKSILVER AT MOUNT DIABLO

Figure 3.8. Gravel mining in Marsh Creek. This early photograph is titled "Gravel for Lone Tree Way. Taking it out of Marsh Creek." The removal of gravel from the creek likely contributed to incision and bank erosion. (Unknown ca. 1905, courtesy of the East Contra Costa Historical Society)

Irrigated Crops (1860s- present)

ECCC has limited surface water resources and low rainfall, so at an early date farmers began to irrigate with surface water from the San Joaquin River and with groundwater (fig. 3.9). To access groundwater, artesian wells were bored near the coal mines as early as 1860 (*Daily Alta California* 1860), and by 1877 this had grown so that "one sees a large number of wind mills" near Antioch (*Antioch Ledger* 1877). Irrigation initiatives organized to draw water from the San Joaquin or dig to reach groundwater. By the early 20th century, farmers began to form irrigation districts.

Irrigation allowed farmers to shift from grains to higher value crops such as fruits and vegetables. By the end of the 19th century, grain production had peaked and begun to decline as irrigation allowed orchards to spread through the dry eastern portion of the county. Readily available pesticides and increased access to markets through the growing railway system allowed farmers to more profitably transition to fruits and vegetables (Hulaniski 1917; fig. 3.10). The decline of grain was hastened by competition from the Midwest and instability in the grain market. This conversion to orchards and vegetables was recorded by historians:

> Here within the past 20 years has been a complete transformation from the region of grain and hay raising to an orchard and vegetable district, where an almost limitless variety of high quality fruits and vegetables grow. (Purcell 1940)

In time, the overdraft of groundwater and excessive diversions of water from the Sacramento-San Joaquin Delta led to salt-water intrusion to the local aquifers. Eventually in the 1940s the Contra Costa Canal, part of the Central Valley Project, was constructed to bring water from the Delta to Contra Costa County bringing relief to farmers (Rowland 1967). This canal draws water from the San Joaquin River near both Knightsen (Rock Slough) and Discovery Bay (Old River).

Figure 3.10. Antioch fruit drying. (Palnae Drug Company postcard ca. 1909, courtesy of the Antioch Historical Society)

Figure 3.9. Two canals. Canals such as these were dredged to carry water to and from the San Joaquin River. At left, "Dredged canal connecting with Indian Creek" (likely a reference to Indian Slough) shows a canal that provided irrigation water. At bottom, "View of Kellogg Creek ditch of the Byron-Bethany irrigation district," shows Kellogg Creek channelized to carry flood water rapidly away from farmland to the San Joaquin River. (Left: Unknown n.d., courtesy of the Antioch Historical Society; Bottom: Unknown n.d., courtesy of the Pittsburg Historical Society)

This scope of country, lying east of the Mount Diablo range, suffers with a minimum of rainfall, and its sandy soils soon become parched, and its vegetation withered, rendering the crops uncertain. Whenever full irrigation can be practiced by the arrested waste of waters, during copious rains, and from the San Joaquin River, or artesian wells, it will be sought.

—STRENTZEL 1876
IN SMITH AND ELLIOTT 1879

Urban Development, Water Management, and Protection

Toward the end of the 20th century, the growing Bay Area began to expand into ECCC, concentrated in the towns surrounding Highway 4. In the 1990s the population in the region grew by 43%, and Brentwood became the fastest growing city in the U.S., reaching 152% growth in one year (Jones & Stokes 2006). With this urban growth, agriculture has declined to 18% percent of total area – and now occupies an area roughly equal to the area covered by "urban" – as mapped by the HCP (Jones & Stokes 2006).

This growth represents a transformation in land use and infrastructure for urbanized areas (fig. 3.11). Along with (and to support) growing urbanization, the past century has seen many modifications to the ECCC water system for irrigation, ranching, urban water supply, and flood control. Many creeks have been channelized for flood control (see chapter four) and a number of reservoirs and stock ponds have been created for flood control and water storage. Major reservoirs include the Antioch Municipal Reservoir (1926), Marsh Creek Reservoir (1963), Contra Loma Reservoir (1965), and Los Vaqueros Reservoir (1998). The partial completion of the Contra Costa Canal in 1940 brought additional water to the county and relieved pressure on groundwater supplies in Antioch and Pittsburg (Rowland 1967).

Another trend through the 20th century has been towards increasing land protection. The newly created Mount Diablo State Park protected the upper slopes of Mount Diablo in 1931, and in 1971 the East Bay Regional Parks District expanded into East Contra Costa, making its first aquisition in 1973 at Black Diamond Mines (Adams pers. comm.). The implementation of the County Urban Limit Line and the recent completion of the ECCC HCP/NCCP have helped to continue the trend towards an expansion of protected lands.

Although cattle, grain, irrigated crops, and urbanization reached East Contra Costa in successive waves, none has succeeded in entirely replacing the previous industry (fig. 3.12, 3.13). The 1939 soil survey describes how these land use types have worked together over the past century:

> The present-day agriculture consists of the production of fruits, nuts, and vegetables on the flatter valley plains; the production of grain, hay, and forage on the foothills; and the grazing of cattle and sheep over the pasture lands of the valleys and the steeper uncultivated hill and mountain lands. (Carpenter and Cosby 1939)

Grazing continues to be a significant form of land use today on parklands and other open spaces within the study area, and has reclaimed some of the marginal land that had been converted to grain crops (Carpenter and Cosby 1939, East Contra Costa Soil Conservation District et al. 1959, Jones & Stokes 2006, Cain and Walkling 2006).

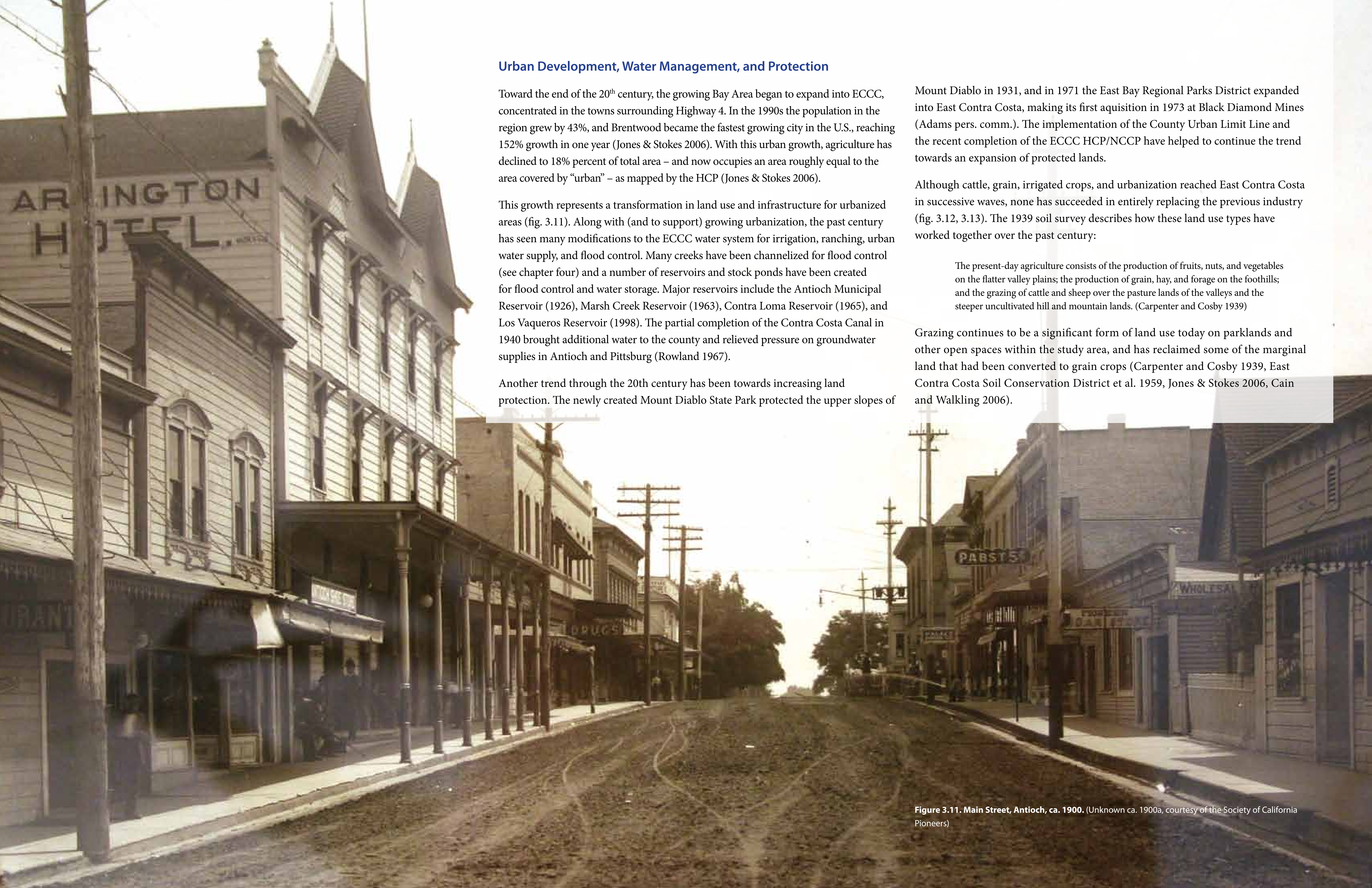


Figure 3.11. Main Street, Antioch, ca. 1900. (Unknown ca. 1900a, courtesy of the Society of California Pioneers)

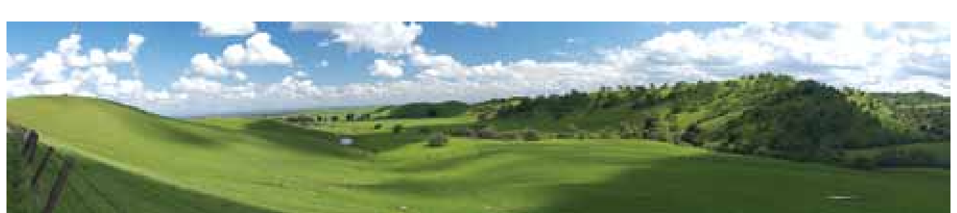
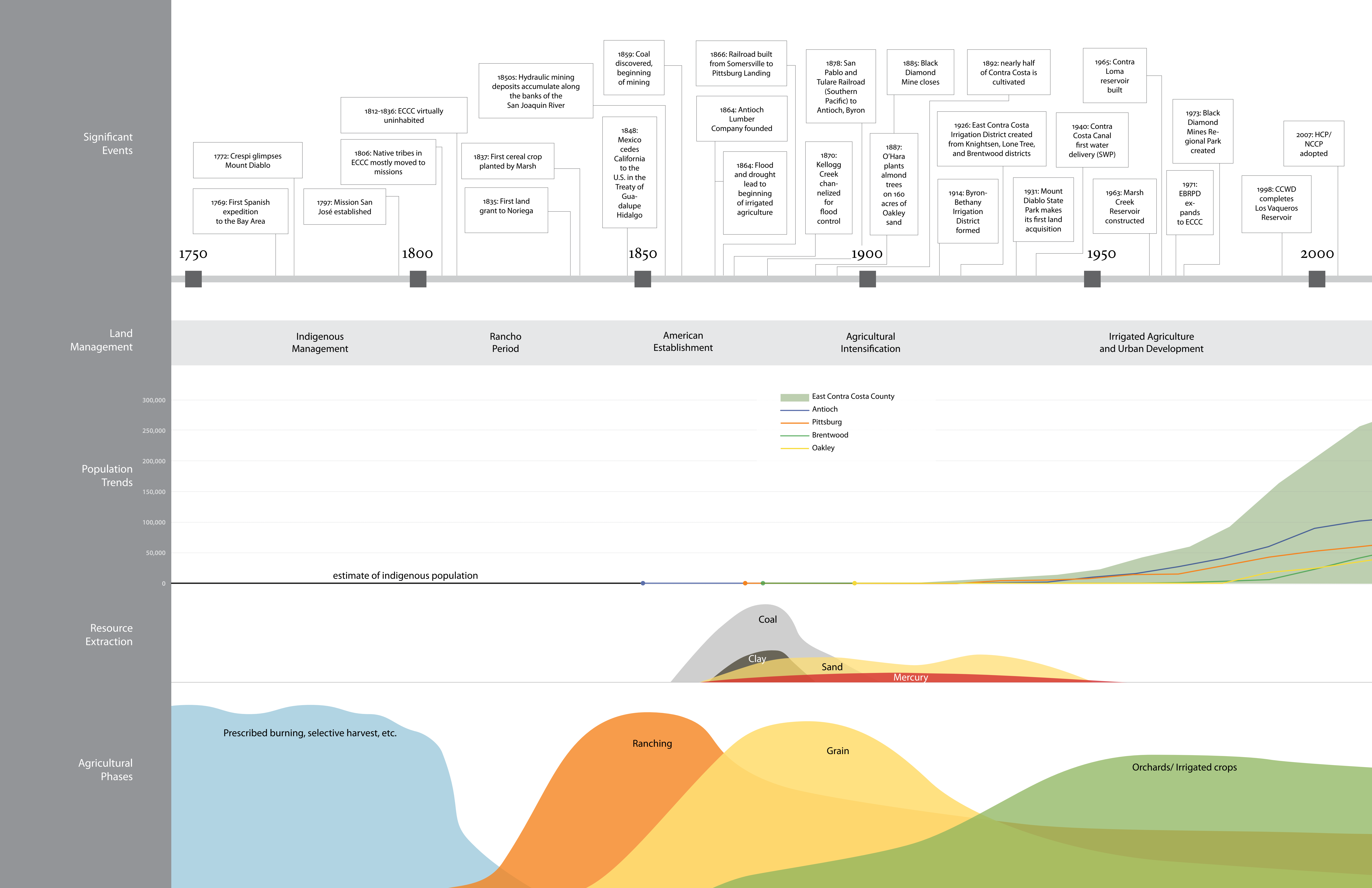


Figure 3.12. Land use in ECCC. Today the landscapes of ECCC record a variety of human uses, from rangeland, dryland farming, windmills, and golf courses to armored creek banks and rural residential development. The urban developments of Antioch, Pittsburg, Brentwood, Byron, and Oakley cover much of the plains area beyond the rolling upland hills. (Images by Scott Hein, www.heinphoto.com)

Figure 3.13. Conceptual land use timeline. (opposite page) This timeline shows important events and land use trends in ECCC over the past 250 years. We divided the timeline into five land management eras, which are matched with four agricultural phases, shown conceptually at the bottom of the diagram. We also included conceptual curves representing major resource extraction efforts. Both the agricultural and resource extraction curves are not shown to scale, and are based on a qualitative understanding of trends in the historical record rather than acreages of land or quantities of a particular resource that were extracted. Population data are from the U.S. Census Bureau. (ECCC total population is based on a sum of all ECCC towns, including some not shown.)



Significant Events
1769: First Spanish expedition to the Bay Area
1772: Crespi glimpses Mount Diablo
1797: Mission San José established
1806: Native tribes in ECCC mostly moved to missions
1812-1836: ECCC virtually uninhabited
1835: First land grant to Noriega
1837: First cereal crop planted by Marsh
1850s: Hydraulic mining deposits accumulate along the banks of the San Joaquin River
1848: Mexico cedes California to the U.S. in the Treaty of Gua-dalupe Hidalgo
1859: Coal discovered, beginning of mining
1864: Antioch Lumber Company founded
1864: Flood and drought lead to beginning of irrigated agriculture
1866: Railroad built from Somersville to Pittsburg Landing
1870: Kellogg Creek chan-nelized for flood control
1878: San Pablo and Tulare Railroad (Southern Pacific) to Antioch, Byron
1885: Black Diamond Mine closes
1887: O'Hara plants almond trees on 160 acres of Oakley sand
1892: nearly half of Contra Costa is cultivated
1914: Byron-Bethany Irrigation District formed
1926: East Contra Costa Irrigation District created from Knightsen, Lone Tree, and Brentwood districts
1931: Mount Diablo State Park makes its first land acquisition
1940: Contra Costa Canal first water delivery (SWP)
1963: Marsh Creek Reservoir constructed
1965: Contra Loma reservoir built
1971: EBRPD ex-pands to ECCC
1973: Black Diamond Mines Re-gional Park created
1998: CCWD completes Los Vaqueros Reservoir
2007: HCP/ NCCP adopted
1750
1800
1850
1900
1950
2000
Land Management
Indigenous Management
Rancho Period
American Establishment
Agricultural Intensification
Irrigated Agriculture and Urban Development
Population Trends
300,000
250,000
200,000
150,000
100,000
50,000
0
East Contra Costa County
Antioch
Pittsburg
Brentwood
Oakley
estimate of indigenous population
Resource Extraction
Coal
Clay
Sand
Mercury
Agricultural Phases
Prescribed burning, selective harvest, etc.
Ranching
Grain
Orchards/ Irrigated crops

CLIMATE HISTORY

Climate and weather patterns in ECCC, as elsewhere, 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 (3.14). Over long time scales, climate causes shifts in habitat distribution and abundance. Shorter-term climatic variation influences native habitat patterns indirectly by affecting land use, as droughts can instigate greater reliance on groundwater, new irrigation practices, or the failure and abandonment of a crop; extreme winter floods can catalyze the construction of improved flood protection channels or alter riparian habitat (fig. 3.15). Short-term climatic variation also can have a direct effect on plant diversity and cover (Bartolome et al. 2004). Historical landscapes and land use change should be interpreted within the context of climate history.

ECCC has a Mediterranean climate, characterized by high inter- and intra-annual variability. Virtually all precipitation occurs between the months of October and April. In the higher elevations, precipitation can occasionally come as snow which lasts for two to three days (USDA 1977). Location and topography are important determinants of East Contra Costa's climate patterns (USDA 1977). The region is affected by the San Francisco Bay Area's maritime climate, resulting in moderated temperatures and bringing winds through the Golden Gate in the summer. Mount Diablo is defined as the boundary between the cool climate type of the coast and the hot climate type of the Central Valley (Bowerman 1944). Precipitation varies substantially across the region, which reflects elevation and proximity to the coast (USDA 1977). The presence of Mount Diablo creates a rain shadow effect, resulting in approximately 10 inches more precipitation at the mountain's summit than in the lowlands.

Consistent records at established stations within Eastern Contra Costa only date back to the 1920s (though some data does exist as shown in fig 3.16). Therefore, we used regression methods to estimate precipitation at two stations (Antioch 1E, WRCC and Mount Diablo Junction, WRCC) from long-term records from Livermore (dating back to 1872) and San Francisco (dating back to 1850). ECCC stations were well correlated with the Livermore precipitation ($R^2 > 0.87$). According to these estimates, the average annual precipitation on Mount Diablo is 24 inches, with a range from 9 (in 1976) to 47 (in 1862) inches (see fig. 3.14). In Antioch, average annual precipitation is only 13 inches, with a range from 4 (in 1976) to 29 (in 1983) inches.

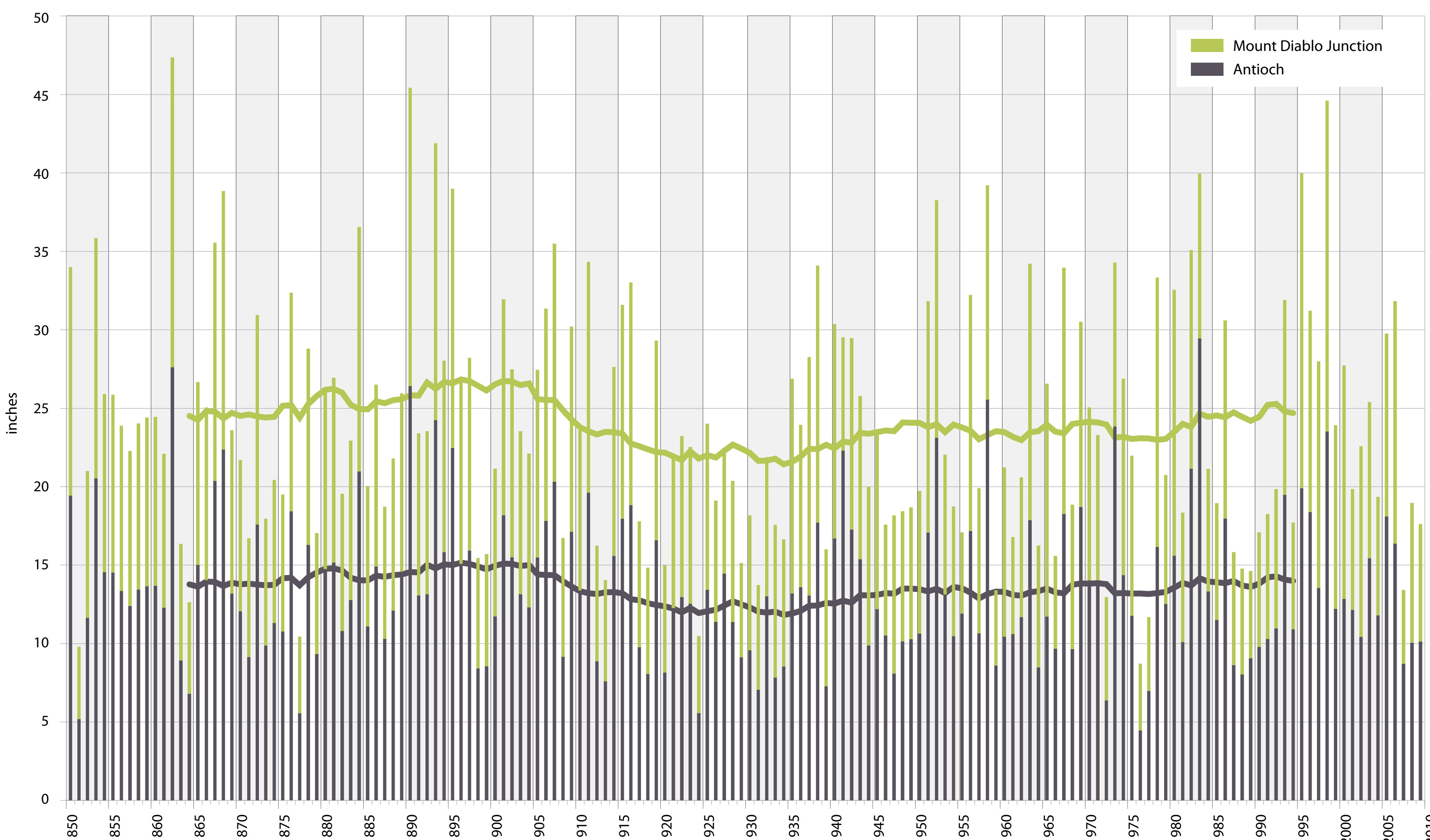
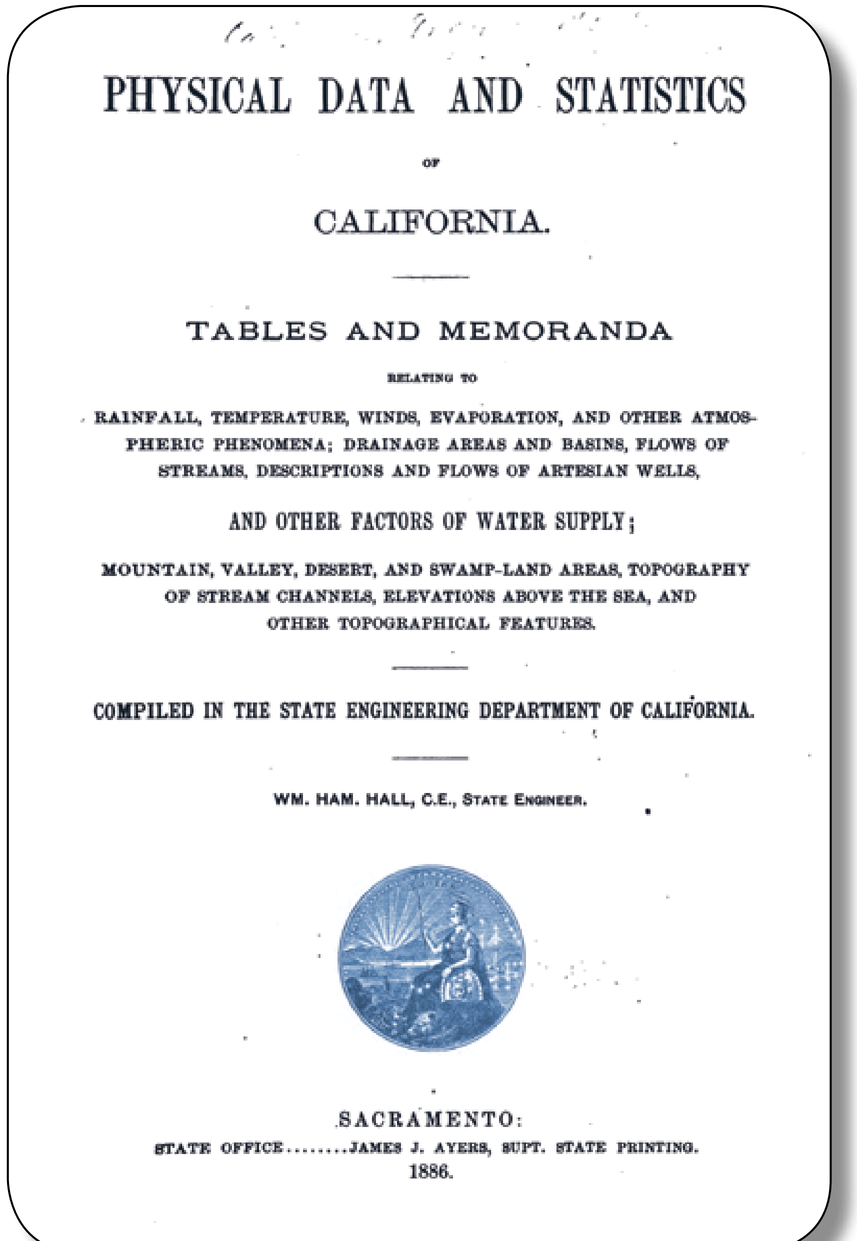


Figure 3.14. ECCC rainfall. (left) This graph depicts annual precipitation and the 30-year running average (the average of the preceding and succeeding 15 years) for the Mount Diablo Junction station (in green) and the Antioch station (purple). Data prior to 1952 for Mount Diablo and prior to 1926 and after 1975 (for Antioch) were estimated using regression from Livermore and San Francisco records ($R^2 = 0.91$; WRCC, Golden Gate Weather Services). The Mount Diablo Junction station receives less rainfall than the summit. Year indicated on the graph refers to the water year (July to June), so the year 1850 represents rainfall from July 1849 to June 1850.

Figure 3.15. Marsh Creek flooding. (below) This picture shows flooding in the very northeast corner of ECCC, at the edge of the historical tidal marsh and looking east across the Delta. This area would have been part of the natural overflow zone of Marsh Creek. (Image courtesy of Contra Costa County)



PHYSICAL DATA AND STATISTICS

OF

CALIFORNIA.

TABLES AND MEMORANDA

RELATING TO

RAINFALL, TEMPERATURE, WINDS, EVAPORATION, AND OTHER ATMOSPHERIC PHENOMENA; DRAINAGE AREAS AND BASINS, FLOWS OF STREAMS, DESCRIPTIONS AND FLOWS OF ARTESIAN WELLS,

AND OTHER FACTORS OF WATER SUPPLY;

MOUNTAIN, VALLEY, DESERT, AND SWAMP-LAND AREAS, TOPOGRAPHY OF STREAM CHANNELS, ELEVATIONS ABOVE THE SEA, AND OTHER TOPOGRAPHICAL FEATURES.

COMPILED IN THE STATE ENGINEERING DEPARTMENT OF CALIFORNIA.

WM. HAM. HALL, C.E., STATE ENGINEER.

SACRAMENTO:
STATE OFFICE........JAMES J. AYERS, SUPT. STATE PRINTING.
1886.

Figure 3.16. State weather data. This state-compiled rain and snow data for the 1880s was collected to better understand "the water supply and demand features of irrigation questions, and the flood problems, in the great valleys of the State" (Hall 1886b). Shown at right are precipitation levels for three rain stations in East Contra Costa County.

PRECIPITATION TABLE, No. 24. COMPILED BY THE STATE ENGINEERING DEPARTMENT. CALIFORNIA.

AUTHORITY: C. P. R. R. Co. (Joseph S. Hall.)

Monthly: Rain and Melted Snow. In Inches. MOUNT DIABLO. *Seasonal: Rain and Melted Snow.* In Inches. CONTRA COSTA COUNTY.

YEARS.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Autumn. Sept.–Nov.	Winter. Dec.–Feb.	Spring. Mar.–May.	Summer. June–Aug.	Tptal Rain.	Total Snow.	Total Precipitat'n.	Remarks.	YEARS.
1874–75	......	......	......	......	......	......	0.63	0.00	0.33	0.62	0.00	0.00	......	......	0.96	0.62	......	......	......	......	1874–75
1875–76	0.00	0.18	9.19	3 11	5.63	5.00	0.00	0.65	0.00	0.00	0.00	0.00	9.37	13.74	0.65	0.00	22.93	7.50	23.76	......	1875–76
1876–77	0.00	2.95	0.27	0.00	4.68	1.89	1.11	0.02	0.45	0.03	0.00	0.00	3.22	6.57	1.58	0.03	10.84	5.00	11.40	......	1876–77
Means	0.00	1.57	4.73	1.56	5.16	3.45	0.58	0.22	0.26	0.21	0.00	0.00	6.30	9.74	1.06	0.21	16.89	6 25	17.58	......	Means.

PRECIPITATION TABLE, No. 21. COMPILED BY THE STATE ENGINEERING DEPARTMENT. CALIFORNIA.

AUTHORITY: Central Pacific Railroad Co.

Monthly: Rain and Melted Snow. In Inches. BYRON. *Seasonal: Rain and Melted Snow.* In Inches. CONTRA COSTA COUNTY.

YEARS.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Autumn. Sept.–Nov.	Winter. Dec.–Feb.	Spring. Mar.–May.	Summer. June–Aug.	Total Rain.	Total Snow.	Total Precipitat'n.	Remarks.	YEARS.
1879–80	0.00	0.00	0.95	1.28	0.92	1.02	0.79	5.13	0.18	0.00	0.00	0.00	0.95	3.22	6.10	0.00	10.27	0.00	10.27	......	1879–80
1880–81	0.00	0.00	0.53	7.56	3.46	1.68	0.91	1.91	0.00	0.00	0.00	0.00	0.53	12.70	2.82	0.00	16.05	0.00	16.05	......	1880–81
1881–82	0.00	0.04	1.00	1.80	1.15	1.02	3.11	0.72	0.00	0.00	0.00	0.00	1.04	3.97	3.83	0.00	8.84	0.00	8.80	......	1881–82
1882–83	0.02	0.97	1.69	0.32	3.09	0.25	1.91	0.17	2.38	0.00	0.00	0.00	2.68	3.66	4.46	0.00	9.92	8.00	10.80	......	1882–83
1883–84	0.00	0.80	0.53	0.71	2.41	4.15	5.61	2.50	0.00	1.54	0.00	0.00	1.33	7.27	8.11	1.54	18,25	0.00	18.25	......	1883–84
Means	0.00	0.36	0.94	2.33	2.21	1.62	2.47	2.09	0.51	0.31	0.00	0.00	1.30	6.16	5.06	0.31	12.67	1.74	12.83	......	Means.

PRECIPITATION TABLE, No. 19. COMPILED BY THE STATE ENGINEERING DEPARTMENT. CALIFORNIA.

AUTHORITY: Central Pacific Railroad Co.

Monthly: Rain and Melted Snow. In Inches. ANTIOCH. *Seasonal: Rain and Melted Snow.* In Inches. CONTRA COSTA COUNTY.

YEARS.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Autumn. Sept.–Nov.	Winter. Dec.–Feb.	Spring. Mar.–May.	Summer. June–Aug.	Total Rain.	Total Snow.	Total Precipitat'n.	Remarks.	YEARS.
1878–79	0.00	0.00	0.15	0.44	1.57	1.69	1.50	0.73	0.88	0.05	0.00	0.00	0.15	3.70	3.11	0.05	......	......	7.01	......	1878–79
1879–80	0.00	0.77	1.38	1.51	0.85	1.07	1.14	3.65	0.33	0.00	0.00	0.00	2.15	3.43	5.12	0.00	......	......	10.70	......	1879–80
1880–81	0.00	0.00	0.00	0.00	1.74	1.54	1.11	1.30	0.00	0.00	0.00	0.00	0.00	3,28	2.41	0.00	......	......	5.69	......	1880–81
1881–82	0.00	0.00	0.95	1.89	0.95	1.29	2.35	0.25	0.00	0.00	0.00	0.00	0.95	4.13	2.60	0.00	......	......	7.68	......	1881–82
1882–83	0.13	1.02	2.49	0.75	1.19	0.48	1.99	0.60	2.25	0.00	0.00	0.00	3.64	2.42	4.84	0.00	......	......	10.90	......	1882–83
1883–84	0.13	0.70	0.55	0.33	3.50	3.62	5.73	2.62	0.00	1.15	0.00	0.00	1.38	7,45	8.35	1.15	......	......	18.33	......	1883–84
Means	0.04	0.42	0.92	0.82	1.63	1.61	2.30	1.53	0.58	0.20	0.00	0.00	1.38	4.07	4.41	0.20	......	......	10.05	......	Means.

Local historical information, such as written accounts of explorers, surveyors, and residents, provides corroborating evidence and offers information concerning climatic events that occurred prior to standardized meteorological data collection. Accounts of floods and droughts reveal years of above or below average rainfall that were particularly damaging and may therefore have had substantial effects on the landscape (fig. 3.17). The combination of precipitation records, longer-term climatic analyses, and historical accounts allows for the reconstruction of the historical climatic context. Cartographic and narrative evidence of ponds or wetlands were considered in relation to the timing of wet and dry years.

Numerous accounts and local histories of East Contra Costa recount the critical flood and drought years, and are summarized here. The winter of 1841 and 1842 had, by one account "three times as much rain this winter as they ever knew in one season before" (Bidwell [1842]1937). Just prior to that, in the summer of 1841, settlers visiting John Marsh were told that "there had been no rain for eighteen months" (Lyman 1931). In the early historical period, decades marked by floods include 1750-70, and 1810-20 (Sullivan 1982 in Malamud-Roam et al. 2007). Other significant flood years were 1849-50, 1852-3, 1861-2, 1866-7, 1867-8, 1871-2, 1889-90, 1894-5, 1910-1, 1907, and 1913-4 (Purcell 1940, Rowland 1967, Leighton 2001).

Drought years appear at a roughly decadal scale, the severity of which varies significantly. In 1776, Pedro Font made note of a particularly dry year, which facilitated travel across the marshes near San Juan Bautista (Font and Bolton 1933). Relevant to the early settlement period, Benyo (1972) reports that "the year 1851 was very dry, all vegetation was blighted." Other droughts occurred in 1862-5, 1870-1, 1876-7, 1883, and 1898-9 (California Dept. of Agriculture 1892, Purcell 1940, Rowland 1967).

The 1860s was a significant decade in terms of climate events and is of particular interest given the number of important datasets (e.g., General Land Office surveys, early travelers journals) from this period. Of relevance to land use change, one county history states, "The flood year of 1862 was succeeded by three dry years, the most disastrous drought on record in the history of California…From this period dates the beginnings of irrigation on a large scale." (Purcell 1940).

Figure 3.17. Crossing wet and dry. The railroad crossing at Knightsen, depicted in 1939 (top left) and 1952 (top right), shows the effect of different rainfall events. (The intersection of the railroad and county road is marked with a red circle in both photographs.) The year that the historical aerials were taken, 1939, was a dry year, with precipitation in Antioch less than half of average. This contrasts with widespread flooding in 1952. The bottom image shows detail of flooding near Marsh Creek - note the people rowing down the street. Major flooding was controlled when the Marsh Creek flood control channel was constructed in the 1960s, although localized runoff can still result in minor flooding. (Top left: USDA 1939, courtesy of Contra Costa County and Map & Sciences Library, UC Berkeley; Top right: Contra Costa County Flood Control 1952, courtesy of Contra Costa County; Bottom: courtesy of Contra Costa County)

CHAPTER 4
STREAMS AND RIPARIAN HABITATS

The farmers in the vicinity of Point of Timber have been at considerable expense to dig a canal to carry the surplus water of the Kellogg creek to the tule lands, lest damage should be sustained by overflow of the upland. Last winter…it broke over the bank in one place and partially irrigated several acres of land bordering on the canal.

— ANTIOCH LEDGER 1874

Despite occupying a relatively small area compared to other habitat types, streams and associated riparian habitats provide an extremely important array of ecological and hydrogeomorphic services (NRC 2002). East Contra Costa County (ECCC) streams and riparian zones provide habitat for a range of native species, including Western pond turtle (*Clemmys marmorata*), California red-legged frog (*Rana aurora draytonii)*, Golden eagle (*Aquila chrysaetos*), and Swainson's hawk (*Buteo swainsoni*) (Jones & Stokes 2006). Specific combinations of riparian vegetation and in-stream aquatic habitat are important for assemblages of native fish, songbirds, waterfowl, and other species (fig. 4.1). 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). In addition, invasive species along and within streams can alter support functions and ecological processes.

ECCC has numerous streams, many of which have been highly impacted by development. Historical research can help reveal where and why changes have occurred to help managers effectively plan restoration. For example, of the many straight channels existing today, some likely flowed through relatively straight historical courses, while others flowed through sinuous channels. Streams in foothill and lowland reaches with limited riparian cover today may have historically had more extensive riparian tree cover, or they may have historically been bordered by low grasslands (Jones & Stokes 2006). Species dependent on dry season aquatic resources, including waterfowl and covered species such as steelhead and red-legged frog, may have relied on springs, pools, perennial reaches, or wetlands that could be recovered through restoration efforts.

To address these and other possible scenarios, we evaluated several different attributes of local stream systems. We compiled a detailed map of pre-modification drainage patterns to document changes in channel position and alignment, drainage density (miles of channel per area), and connectivity. We compared riparian canopy cover in 1939 and 2005 aerial imagery along major channels to assess potential expansion or retraction of riparian cover. We assembled available evidence describing dry season conditions and persistent pools on stream channels to address questions about base flow prior to surface water diversions and groundwater withdrawal. In the following chapter, we describe our methods and analyze key results before more broadly discussing our findings. Because of the particular interest in fish habitat, we provide an extensive discussion of probable use of the ECCC landscape by native fish.

Figure 4.1. Streams of Contra Costa County. A) Riparian trees along sinuous Sand Creek. B) Sycamores along Curry Creek. C) "From Raffet Place at Kellogg Creek...Black hills in background." (A: photo by Seth Adams, Save Mount Diablo; B: photo by Scott Hein, www.heinphoto.com; C) Unknown ca. 1920, courtesy of the California Historical Society)

METHODS

This method section describes several different strategies used to document characteristics of ECCC streams and riparian habitats.

Channel Network

The historical stream alignment is based on the contemporary hydrography GIS data of Contra Costa County (CCC 2008), modified where the historical stream course clearly differed from the contemporary alignment. Where historical position was shown within 50 ft of the contemporary position, we maintained the contemporary line feature. This approach avoids the generation of "crisscrossing" lines representing the same feature, which could potentially be mistaken for channel migration. Although this method will not capture all changes, it highlights significant changes while preventing us from over-mapping change.

To maintain a consistent depiction of channel density over time, we attempted to map creek reaches only to the level of detail shown in the contemporary data provided by Contra Costa County. This standard excludes some small, intermittent or ephemeral drainages visible in aerial photography, but allows for more accurate comparison between the historical and contemporary stream networks.

To map the historical drainage network, we first compared early aerial imagery (USDA 1939) to contemporary imagery (USDA 2005) to identify post-World War II modifications. To evaluate earlier change we compared the 1939 network with earlier maps (e.g., Britton and Rey 1871, McMahon 1885, Wagner and Sandow 1894, USGS 1901-1918, Arnold and Glass 1914). We also incorporated information from the mid-19th century General Land Office (GLO) land grant and public land surveys (see Drylands chapter six for more discussion of this source). Soils, topography, and landscape features contributed to our understanding and depiction of creeks. The final historical creek map represents our best understanding of hydrography prior to significant Euro-American modification. Contributing sources and associated certainty levels for each creek reach are recorded in the GIS attributes.

Constructing the historical drainage network in this region was complicated by the many small, intermittent systems. Absence of a creek in historical maps may indicate that the creek was not considered significant, rather than actual absence. In some cases sources depict some small creeks, or portions of a creek, but not others. For example, one county map (Britton and Rey 1871) shows the tributaries of lower Marsh Creek as discontinuous while still in the hills. However, larger-scale sources indicate that the creeks extended further towards Marsh Creek before forming distributaries. These intermittent, discontinuous creeks may, in some cases, have had poorly defined endpoints that shifted over time due to annual variation in rainfall.

The Contra Costa County contemporary hydrography GIS data (CCC 2008) was used for comparison. This data codes creek segments with the material used in construction and whether the segment runs above or below ground. This source also digitizes straight channel segments through ponds and reservoirs. The lengths calculated from this data include all length along a creek, including these bodies of open water. Historical creek lengths include only length of defined channel, and do not continue across open bodies of water. As a result, channels that have been replaced by reservoirs appear in our results as modified creeks rather than miles of creek lost.

For the past/present comparison, we compared only fluvial channels (i.e., upstream of the historical tidal marsh boundary), excluding contemporary drainages that extend into the historical tidal marsh. Excluding these tidal drainages allowed for more accurate comparisons of creek length.

Dry Season Flow

Although we did not display historical dry season flow on the habitat map, we did code each reach as perennial or intermittent based on the historical U.S. Geological Survey (USGS) flow mapping (fig. 4.2, see fig. 4.17). The earliest historical USGS quads for this region date from between 1896 and 1918 and illustrate seasonality of flow by reach. Where a reach did not appear on the USGS, we coded it based on the seasonality of surrounding stream reaches and our understanding of the hydrology of the region. However, we lacked the additional sources needed to map flow patterns along each reach, so perennial and intermittent reaches are not shown on the habitat map.

Riparian Cover

To evaluate change in riparian cover between 1939 and 2005, we classified reaches of each major stream by riparian cover type. These major streams were Kirker, Markley, East Antioch, West Antioch, Mount Diablo, Marsh, Sand, Deer, Dry, Briones, Kellogg, and Brushy creeks. Our classifications attempted to capture functional shifts in canopy cover density. We classified reaches based on four cover types: closed canopy (>60% cover), open canopy (25-60%), sparse canopy (10-25%), and herbaceous (<10% tree cover). These four classes correspond with several density classes applied to our mapping of drylands (Jones & Stokes 2006). As we were not able to easily distinguish shrub cover on the historical aerials, shrubs (shrubby willows, mulefat, etc.) are included within the closed, open, and sparse canopy types. We also included a wetland/aquatic class, to indicate that the stream was passing through a historical or contemporary wetland or aquatic feature (e.g., a lake), and an underground class, for reaches in the contemporary map that have been routed underground (e.g., urban areas). We used a minimum mapping unit of approximately 300 ft, based on the functional stream unit length of 300-600 ft (100-200m) defined by the CRAM (California Rapid Assessment Method; Collins et al. 2008).

Percent cover was estimated visually at a scale of 1:5,000 through side by side comparisons between historical (1939) and contemporary (2005) aerial imagery of each reach. As a result, our analysis of historical riparian cover produces a picture of the 1939 conditions as opposed to the mid-1800s picture we attempt to depict elsewhere.

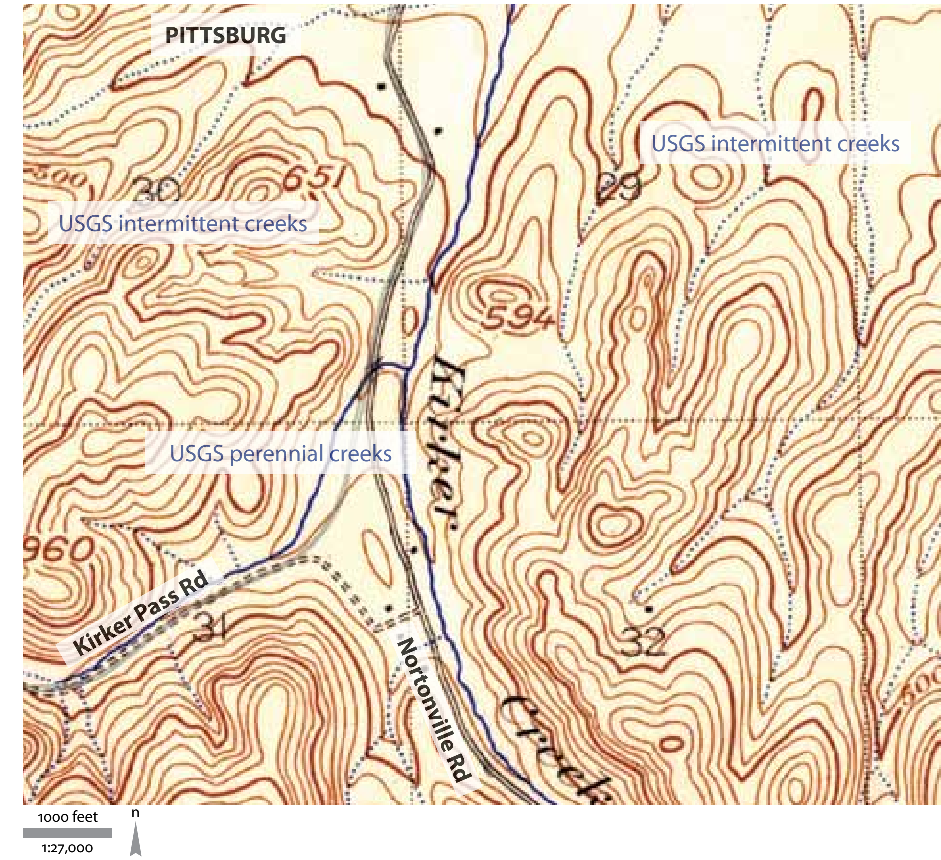


Figure 4.2. Perennial and intermittent stream reaches. Historical USGS quadrangles recorded the seasonality of stream reaches, using a thick "blue line" to indicate a perennial reach and a dashed or dotted line to indicate an intermittent or ephemeral reach. We coded our stream network using this data, although we did not feel confident enough in this source to display it on our habitat map. At bottom left see an image of one of the many intermittent streams in ECCC. (USGS 1896 (Mount Diablo); USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; photo May 14, 2009 by Ruth Askevold)

To build a picture of riparian cover pre-1939 and describe plant composition in riparian corridors, we compiled written descriptions, photographs, and GLO data. To query GLO bearing and line trees along creeks we selected all trees within 160 ft of creek channels. This distance, while arbitrary, appeared to select trees within the riparian corridor. Reducing the size of the buffer to 60 feet reduced the number of trees selected, but did not alter the species composition and appeared to exclude some trees arbitrarily.

Given the current local interest in beavers on Alhambra Creek in central Contra Costa County, we also endeavored to document any evidence for beaver in the region.

RESULTS

This section presents findings on the historical conditions and changes to the drainage network, dry season water resources, and riparian cover.

Discontinuous Streams

Historically, the lower reaches of most streams in ECCC were discontinuous, consistent with many smaller systems throughout the San Francisco Bay Area (see SFEI 1998; Sowers and Richard 2003; Sowers et al. 2006; Grossinger et al. 2008a, b). Rather than maintaining well-defined channels to tidal waters, almost all of the drainages flowing north and east from the Mount Diablo foothills toward the tidal San Joaquin River dissipated into seasonally wet lowlands (fig. 4.3). Historically, Marsh Creek was one of only a few streams in ECCC to flow directly to the tidal marsh.

For example, at the southern boundary of Los Medanos, Surveyor William Lewis (Oct 1860 and 1870) noted a series of dry runs and recorded a "deep creek" as he crossed Markley Canyon. One mile further downstream Leander Ransom (August 1851) noted instead a series of ravines and then, near the current course of Markley Canyon, an area of low bottom, "overflowed during wet season, swampy," created by flow from Markley. The transition from a "deep creek" to a "swampy" lowland area corresponds with changes in topography as the slope of the plains flattens. Markley was substantially incised as it exited the hills and had oak trees growing in the stream bed (fig. 4.4). Lower on the alluvial plain, the channel broadened into a wetland area and the deep canyon disappeared. This transition is clearly visible on both the oblique and vertical historical aerial photographs (Russell ca. 1925, USDA 1939).

Similarly, southeastern drainages such as Frisk, Brushy, and Kellogg creeks split into multiple channels and dissipated into alkali meadow or sank into the ground before reaching the tidal marsh. The point at which Kellogg Creek lost a defined channel bed is well documented in early maps, just as the creek turned east into the alluvial plain (Britton and Rey 1871,Whitney and Hoffman 1873, McMahon 1885, Hall 1886a, Punnett Bros. ca. 1914). This is also the furthest downstream point at

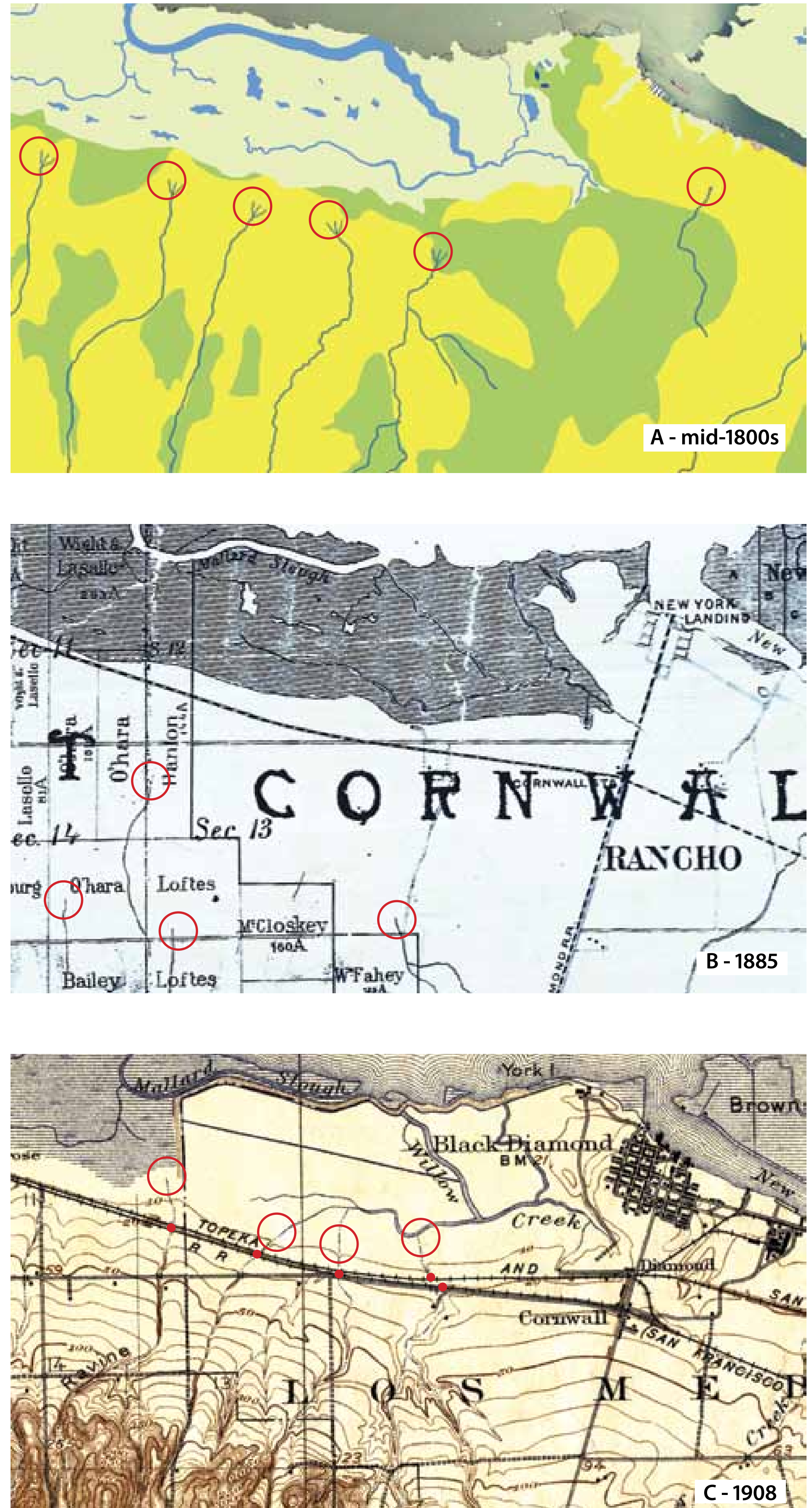


Figure 4.3. Discontinuous northern drainages. A) Most northern drainages did not connect directly to the tidal marsh in the mid-1800s, as shown here in the historical habitat and channel map developed for this project. B) Early maps show the pattern of defined channels extending some distance onto the alluvial plain and then terminating (indicated by red circles) in seasonally wet lowlands. C) By 1908, after the construction of the railroad, many of these drainages connected to the tidal marsh and river. Connection across the railroad tracks is indicated by a red dot; connections to other systems are indicated by red circles. D) The historical drainage pattern (in blue) for this area imposed on the contemporary drainage pattern (in turquoise). (B: McMahon 1885, courtesy of Contra Costa County Public Works Department; C: USGS 1908 (Pittsburg-Antioch); D: USDA 2005, courtesy of NAIP)

which the General Land Office notes describe “Arroyo de la Posa”; further east they describe only scattered timber and a “dry bed,” likely a disconnected stream segment (Norris 1851; Dyer 1861, 1862a). Historically Kellogg Creek spread across the plains after storms, causing problems for farmers. As early as 1874 farmers were at “considerable expense to dig a canal to carry the surplus water of the Kellogg creek to the tule lands, lest damage should be sustained by overflow of the upland” (*Antioch Ledger* 1874). Today the lower reach of Kellogg Creek is channelized (see fig. 4.6, 3.9).

While multiple lines of evidence confirm the presence of discontinuous channels, sources sometimes vary on the position of the transition from well-defined channel to swale/overland flow, and specific evidence is limited on some creeks. We would expect these transition points to be somewhat variable through space and time, associated with major rainfall/sediment transport events.

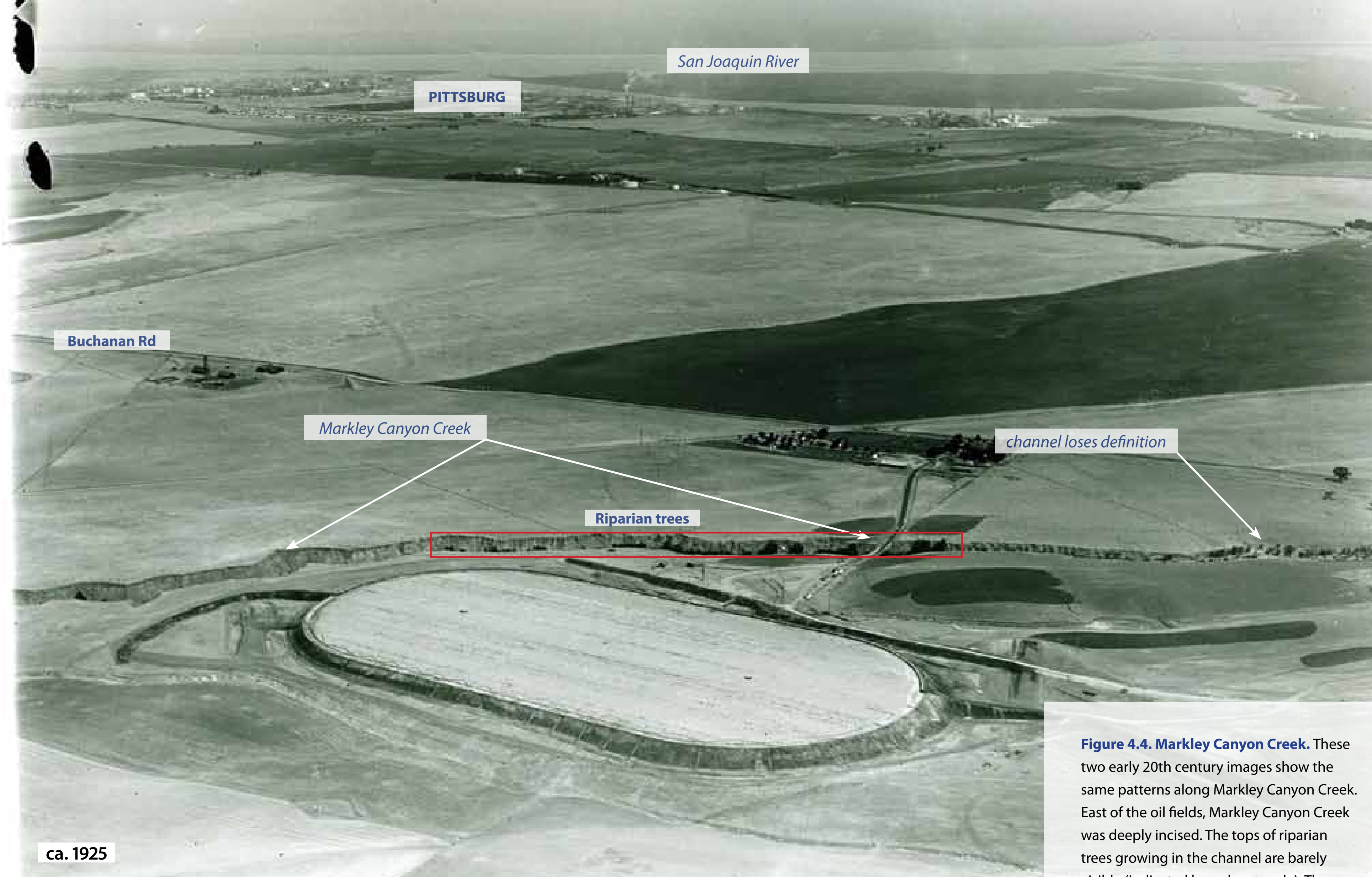
Changes in the Drainage Network

We mapped 477 miles of historical streams in ECCC, slightly more than the mapped 426 miles in the contemporary stream map (fig. 4.5). This difference in length is the result of two opposing trends: channel length has been removed from the contemporary network through straightening meanders and removing distributary channels, while channel length has been added through extensions connecting formerly discontinuous segments to tidal waters. The overall decrease in length at least partially reflects differences in mapping rather than actual change. Although we attempted to map to a level of detail consistent with Contra Costa County 2008, there may be instances where the historical mapping shows more detail than the contemporary stream map.

Seventy-five percent of the contemporary stream network (318 miles) matches the historical network (fig. 4.6). (This percentage includes some drainages that have been modified where those modifications did not move the creek bed more than 50 ft.) The remaining 25% of the contemporary drainage network differs from the historical network, either because a new channel segment has been built to connect previously disconnected reaches, or because a creek reach has been shifted from its historical course.

To analyze stream characteristics, we divided the region by watershed and by geomorphic unit (fig. 4.7, 4.8, see fig. 2.4). Most of the modifications have taken place in the highly developed plains reaches (<200 ft elevation), with some modifications extending into the foothills (200-900 ft). Montane reaches (>900 ft) follow their historical courses in most cases (fig. 4.9, see fig. 4.6). In the montane region, less than 1 mile of the contemporary network, or 1.5% of total length, differs substantially from its historical course.

In the foothill region the contemporary network differs from the historical network for 25% of its 230 mile length. Much of this is due to the construction of the Los Vaqueros Reservoir on Kellogg Creek. Excluding Kellogg Creek, only 12% of the contemporary channel length (22 miles) differs from the historical network. In a



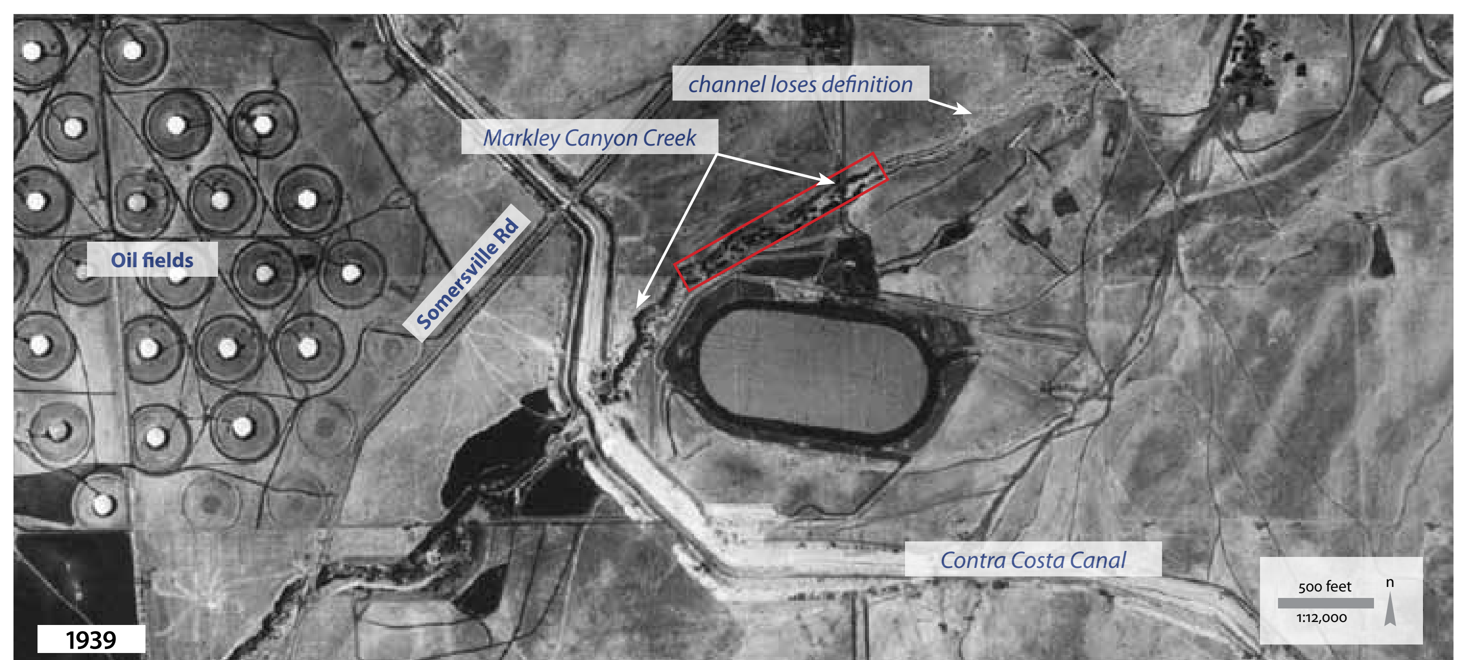


Figure 4.4. Markley Canyon Creek. These two early 20th century images show the same patterns along Markley Canyon Creek. East of the oil fields, Markley Canyon Creek was deeply incised. The tops of riparian trees growing in the channel are barely visible (indicated by red rectangle). The tree tops are particularly noticeable in the oblique photo, looking northwest towards Pittsburg. Continuing further downstream (north), the topography flattened and the creek channel lost definition. (Russell ca. 1925, courtesy of the State Lands Commission; USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley)

Figure 4.5. Creeks of East Contra Costa County. Clockwise, starting with top image: a lush tributary to Marsh Creek near Morgan Territory Road; wetlands on a Kirker Creek tributary; upper Marsh Creek just below Morgan Territory Regional Preserve; high water along Marsh Creek. (Top March 27, 2011 by Brad Heckman, Save Mount Diablo; Bottom right and middle: July 14, 2011 and November 30, 2010 by Scott Hein, www.heinphoto.com; Bottom left December 19, 2010 by George Phillips, Save Mount Diablo)

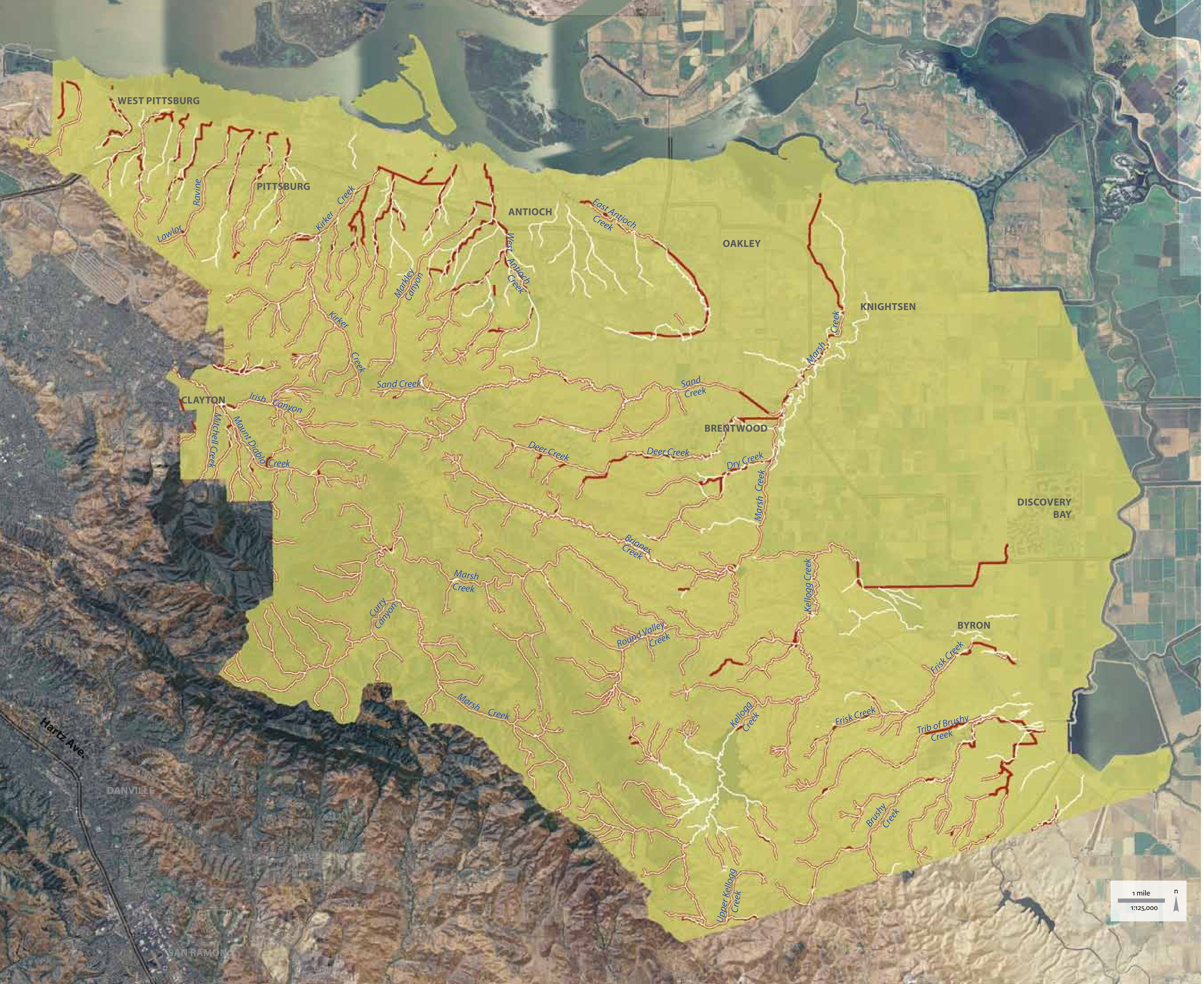


Figure 4.6. Comparison of historical and contemporary drainage network. The historical network (shown in white) had many more discontinuous reaches than the contemporary network (shown in red). Reaches that appear only in red represent areas where a stream segment has been constructed on a course different from the historical course. Reaches that appear in white represent segments of the historical network that have been lost (typically these segments have been replaced by a ditched channel nearby, appearing in red). The combined red and white lines represent reaches where the historical and present-day networks are aligned. Most of the modifications to the stream network occurred in the northern and eastern lowlands (e.g., along Marsh, Kellogg, Brushy, and East Antioch creeks). The particularly prominent red line in the eastern portion of the study area represents the ditched lower reach of historically discontinuous Kellogg Creek. Most channels in the hilly area in the southwest portion of the study area still follow their historical alignments. (USDA 2005, courtesy of NAIP)

few cases, notably along Deer Creek, new channel segments were created where the creek was once discontinuous. However, most modifications did not add stream length, but rather moved the location of the channel.

In the plains region over half (57%) of the 124 miles of contemporary drainages do not match historical alignment. Land in the plains region is largely either agricultural or urban, and creeks have been heavily impacted. Some drainages were straightened and moved to accommodate development, while others have been constructed to connect formerly discontinuous streams with the tidal marsh. (See contemporary data CCC 2008 and Contra Costa County Department of Conservation and Development 2003 for more details on the contemporary network.)

The modification of the plains historical network was most extreme in the northern drainages (Willow, Kirker, East Antioch, and West Antioch), where 82% of the contemporary channel length differs from the historical route. These 40 miles of modified and constructed channel length direct water more rapidly through urban areas and connect creek segments that were historically discontinuous. Historically, almost all of these drainages formed distributaries before reaching the tidal marsh, many of them feeding into swales that formed wet meadows.

The discontinuous lower reaches of Kellogg and Brushy creeks have also been modified. Historically these streams spread into many small, discontinuous segments that fanned out across the plain. These disconnected reaches were filled for agriculture and development, and additional stream length was added to connect these streams directly with the tidal marsh and prevent flooding. Forty percent (17 mi) of contemporary plains stream length in Kellogg and Brushy creek watersheds differs from the historical path (fig. 4.10).

Finally, Marsh Creek and several of its major tributaries (Sand, Deer, and Dry) have been straightened and channelized through the plains (fig. 4.11). The most substantial change was the loss of a 7 mile secondary channel along lower Marsh Creek, the only ECCC example of a double channel (fig. 4.12).

In a few cases creeks may have lost sinuosity through modifications prior to historical documentation, and so were mapped in an already modified condition. We examined three stream reaches that appeared artificially straight in the historical network (on Deer and Marsh creeks and a tributary to Sand Creek) and contrasted them with two that were highly sinuous (on Sand and Briones creeks; fig. 4.13). The less sinuous drainages had sinuosity indices of roughly 1.1-1.3, while the more highly sinuous drainages were between 1.6 and 1.9. All five drainages flowed southeast through the foothills along valley alluvium, and all were continuous over the stretch we examined.

A number of factors could be responsible for the less sinuous reaches. They flow through valleys that were heavily cultivated by 1939, so it is plausible that these small, low flow creeks were artificially straightened to direct them around agricultural fields. However, there are also potential natural explanations for a lack of sinuosity (which is observed on the lower reaches of many Bay Area creeks). The less sinuous drainages may be constrained by the sediment fans of their own small tributaries (fig. 4.14). The creeks may also have had different sediment loads and patterns of deposition, leading to different morphologies. Smaller creeks, such as Deer Creek and the tributary to Sand Creek, may have lacked the energy to cut a channel and the creeks may have been constrained by uplift. More in-depth analysis of the geomorphology of these systems would be needed to establish the cause of the variation and the extent of anthropogenic influence.

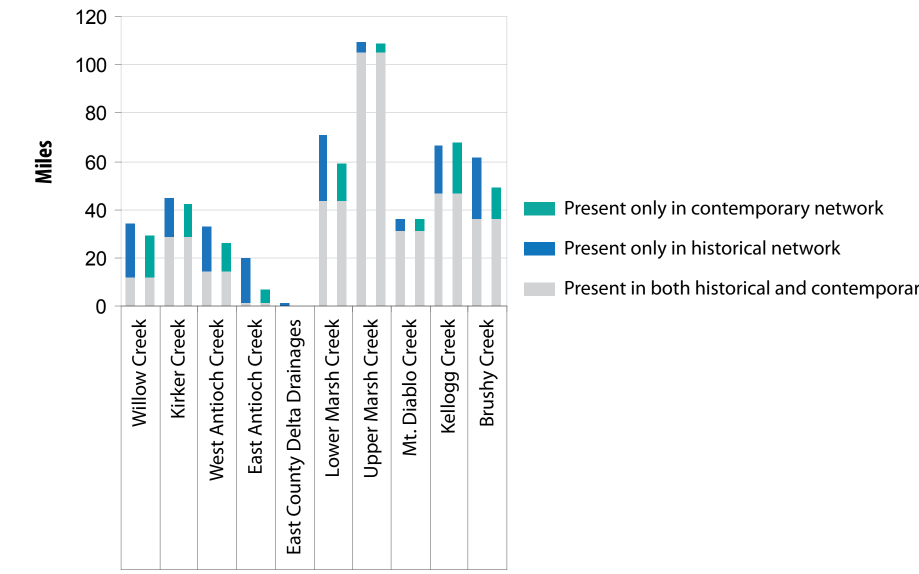


Figure 4.7. Stream modification by watershed. The colored bars represent the miles of each network that differ between historical and present-day periods. Miles of stream present only in the contemporary network are miles that have been added to the contemporary network. Miles of stream present only in the historical network are miles that have been lost from the historical network. Overall, stream length decreased by 51 miles.

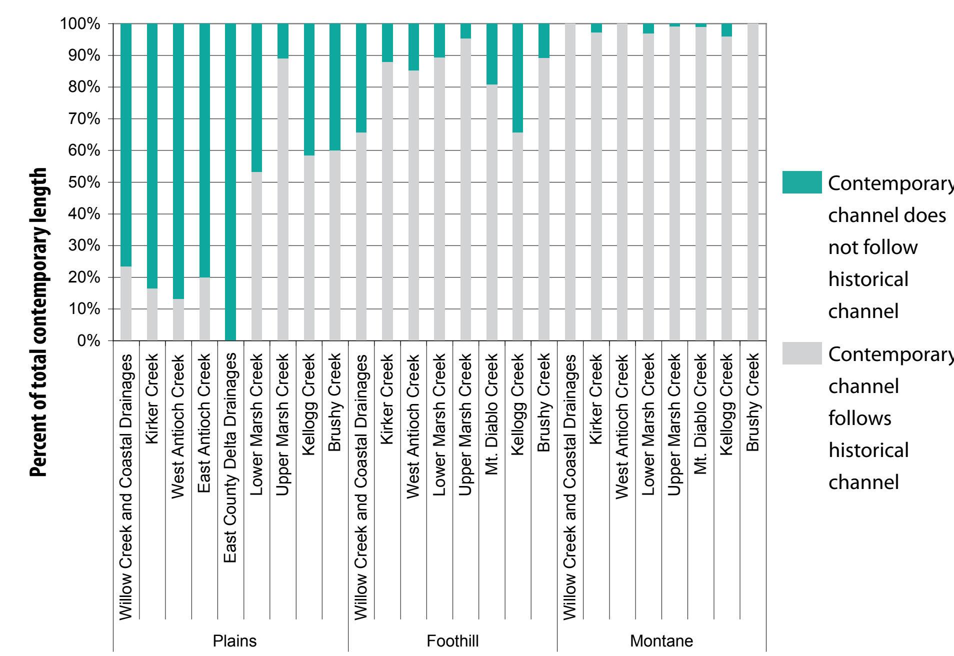


Figure 4.9. Stream modification by watershed and geomorphic unit. In general, stream reaches in the plains geomorphic unit have been heavily modified; foothill and montane units display much less alteration. For more details on the types of altered channels present in ECCC, see the Watershed Atlas (Contra Costa County Department of Conservation and Development 2003).

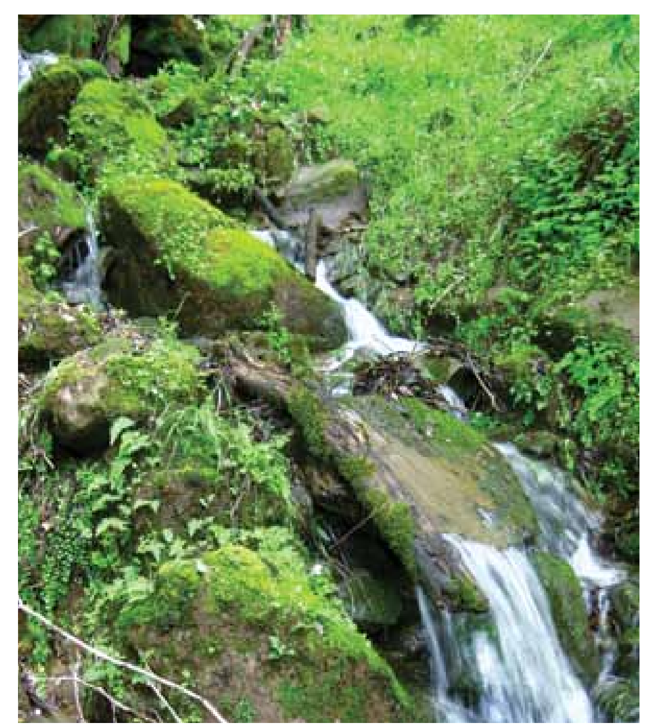


Figure 4.8. Streams by geomorphic unit. (left) From left to right, images of streams in the plains, foothill, and montane geomorphic units. (Left to right: May 9, 2009 by Ruth Askevold; August 28, 2008 by Scott Hein, www.heinphoto.com; March 27, 2011 by Brad Heckman, Save Mount Diablo)

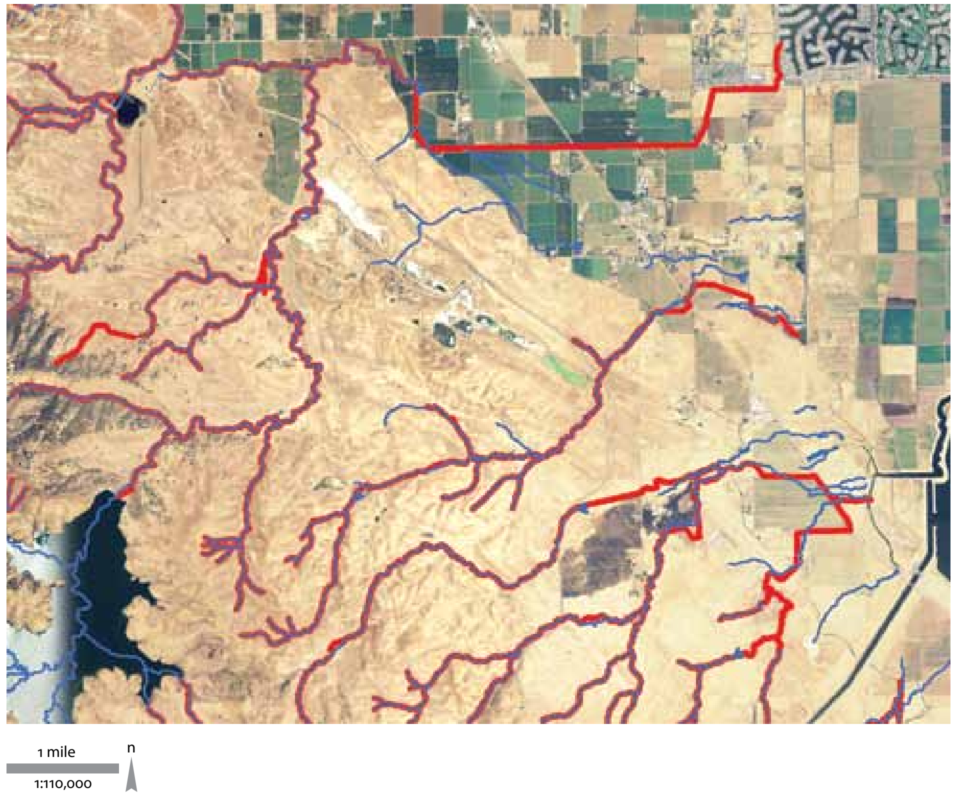
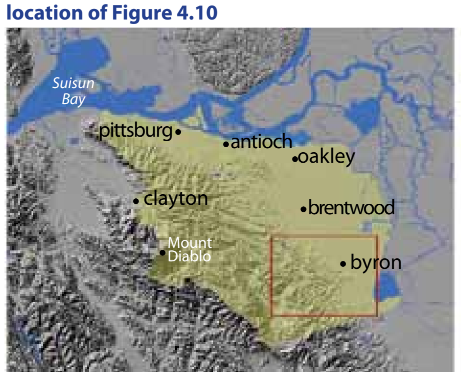
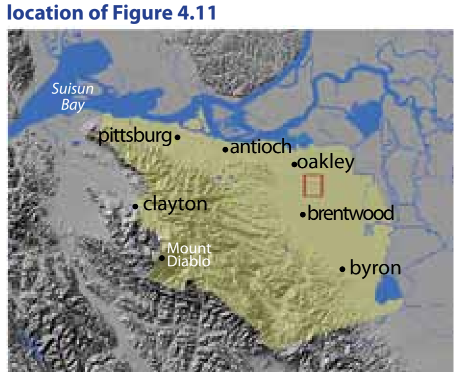


Figure 4.10. Changes in the southeastern drainage network. The contemporary network (shown in red) of Kellogg and Brushy creek watersheds has extended and straightened portions of the historical network (blue) to make it much more continuous. (USDA 1939, courtesy of NAIP)

location of Figure 4.10



location of Figure 4.11



The great bulk of the damage [from floods]*… takes place on the flood plains of Marsh and Kellogg creeks….In the case of Marsh Creek, floodwater leaves the inadequate channel at various points but is prevented by topographic conditions from returning. Instead, it flows northeasterly, impeded by road and railroad embankments, until it is impounded against the dikes of Rock Slough and the Contra Costa Canal. Such flows have inundated as much as 4,900 aces to depths of four feet within the past few years. Major areas remain flooded until the water evaporates, sinks into the ground or pumped over the dikes. Outflow from the flood plain is retarded by the fact that the area borders tidewater.*

—EASTERN CONTRA COSTA SOIL CONSERVATION DISTRICT ET AL. 1959

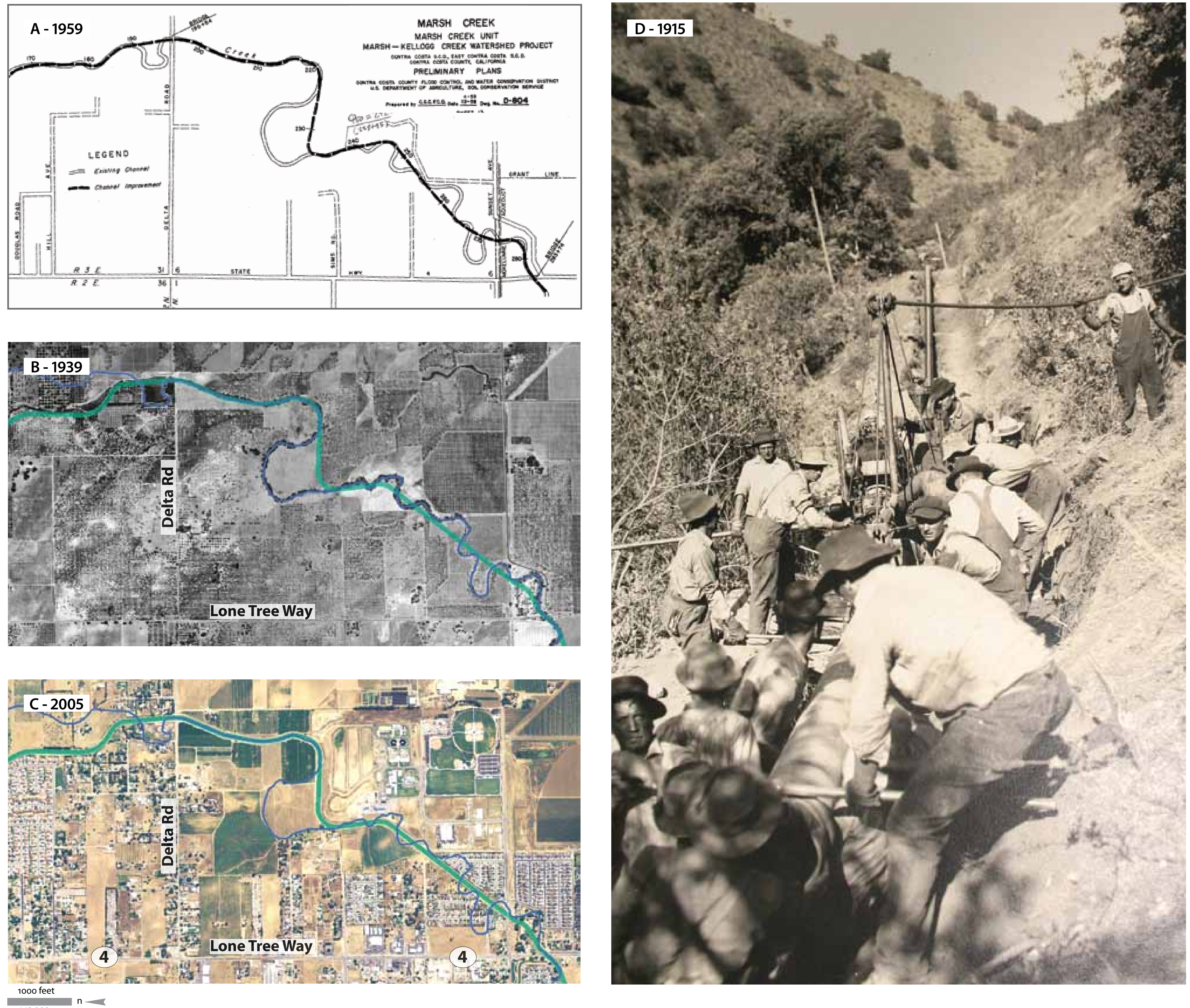


Figure 4.11. Modifications to Marsh Creek. The engineering map (A) shows a 1959 design to remove several meanders from Marsh Creek. These meanders can clearly be seen in the historical aerials (B) and have been removed today (C). In B and C the historical network is shown in blue, overlaid on the present day network shown in turquoise. D) A crew of men installing pipe in Contra Costa Canyon demonstrate another type of human impact on streams. (A: Eastern Contra Costa Soil Conservation District et al. 1959; B: USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; C: USDA 2005, courtesy of NAIP; D: Sanderson & Porter 1915, courtesy of Contra Costa County Historical Society)

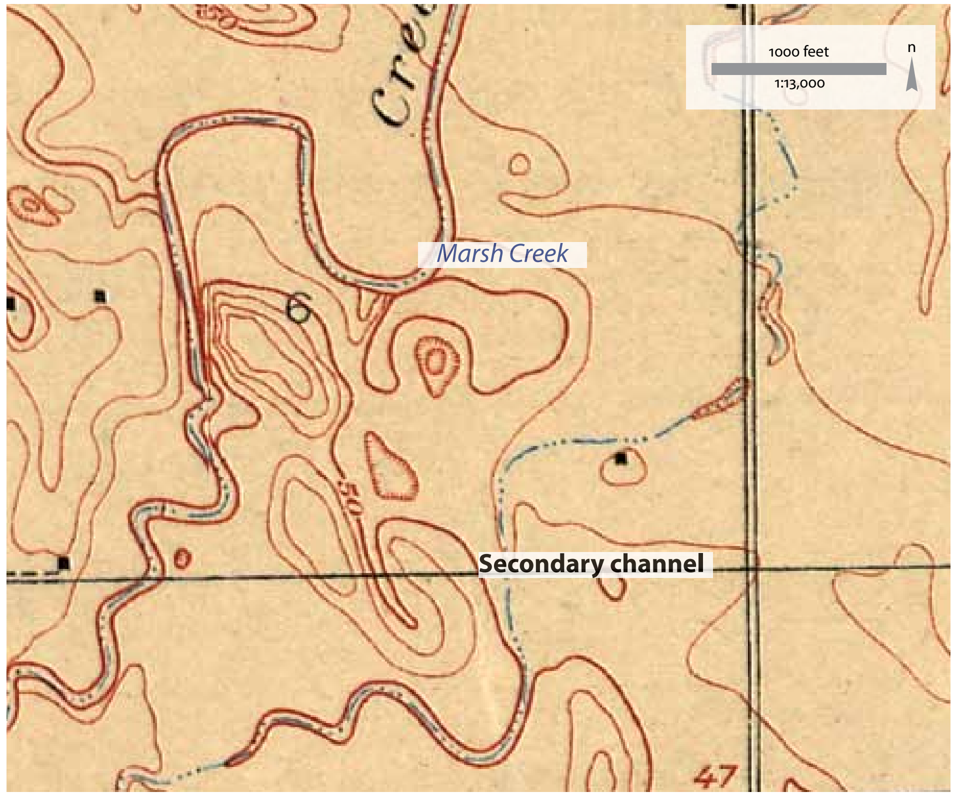


Figure 4.12. Secondary channel of Marsh Creek. (left) Below its confluence with Deer Creek, Marsh Creek historically split into two channels. The eastern channel functioned as an overflow or secondary channel through the historical period, but in prehistoric times may have served as the primary channel of Marsh Creek. Both channels are mapped with a dashed blue line on this 1916 USGS map. (USGS 1916 (Brentwood))

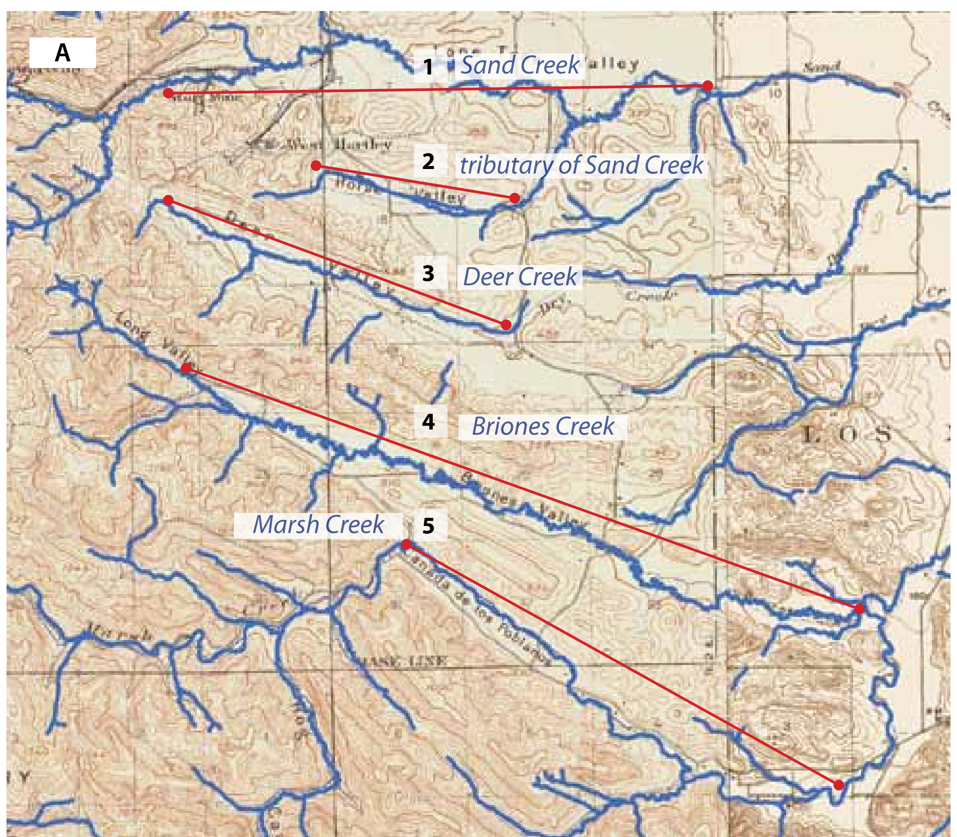
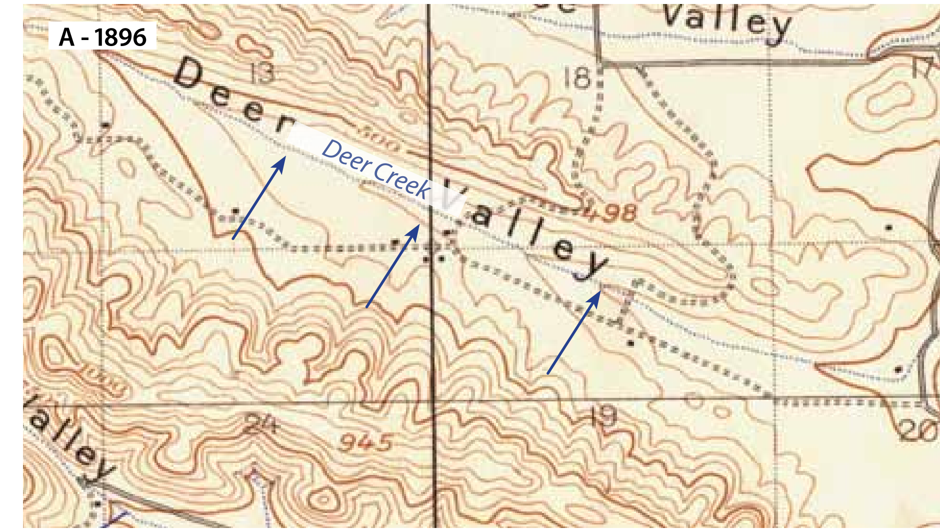


Figure 4.13. Investigation of historical sinuosity. We examined sinuosity for stream reaches running through five parallel valleys. These were sinuous Sand and Briones creeks (1 and 4), and a relatively straight tributary of Sand Creek (through Horse Valley), as well as Deer and Marsh creeks (2, 3, and 5). We calculated sinuosity over the distance shown by the red lines in (A). B) shows a view looking southeast along Briones Creek today. (Map: USGS 1896 (Mount Diablo) and 1916 (Byron); Photo by Abigail Fateman, CCC)



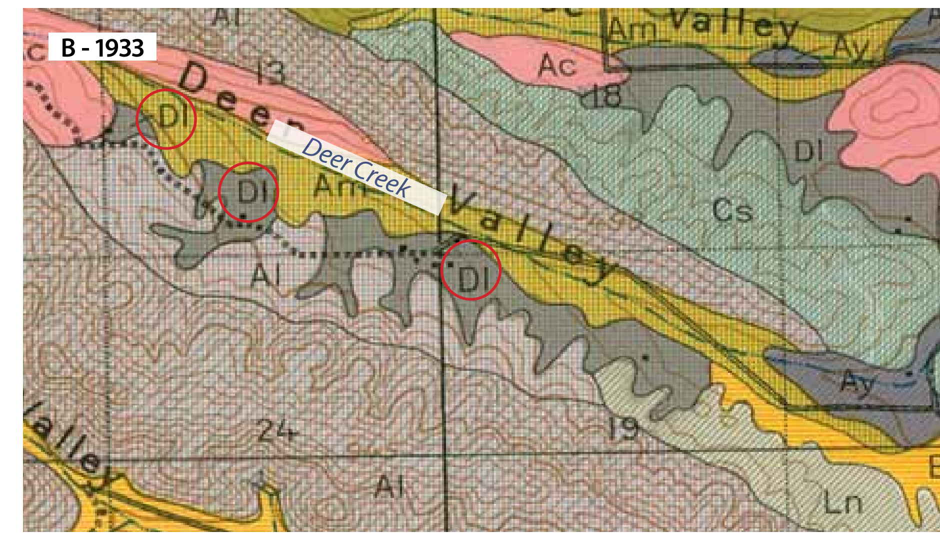
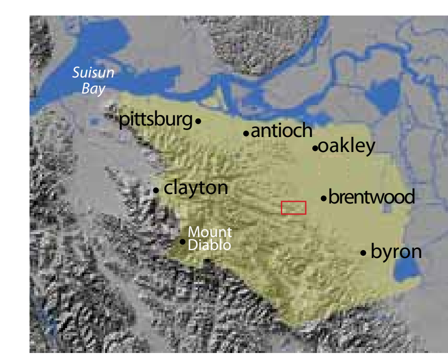


Figure 4.14. Sinuosity of Deer Creek. A) Upper Deer Creek followed a relatively straight course, constrained to the northern edge of its valley. South of the creek, the soil survey (B) shows deposits of Danville clay loam (Dl), shown in dark grey. These alluvial deposits, created by small hillside tributaries, likely helped restrict Deer Creek to the northern side of the valley. The arrows (A) show the direction these tributaries would have pushed Deer Creek. (A: USGS 1896 (Mount Diablo); B: Carpenter and Cosby 1933)



In as much as there is practically no summer flow in Marsh Creek, such use would be confined to the months in which the annual rains occur, or to winter irrigation.

—KEMPKEY 1918, REFERRING TO LOWER MARSH CREEK

Dry Season Water Resources

Most streams in ECCC were historically intermittent or ephemeral, much as they are today. However, a few creeks did contain prominent pools and perennial reaches that persisted into the dry season (here defined as June-October). Pools in particular were an extremely important feature historically. Permanent pools were often fed by groundwater and could remain cool through the hot summer.

The GLO surveys are among the earliest sources documenting reaches with and without persistent dry season water. Surveyors repeatedly described crossing "dry run[s]," and commented on the lack of water in the region as a whole. Surveyors also noted places with dry season water. In July of 1853 (a wet year), Surveyor Sherman Day passed a series of pools in five locations along a tributary to Brushy Creek, upper Frisk Creek, and Kellogg Creek. Kellogg Creek was historically known as "Arroyo del Poso," with "poso" or *poza* loosely translatable as pool of standing water, suggesting that even in years of normal rainfall, water may have persisted into the dry season. The surrounding land grant, Los Vaqueros, was valued as ranch land for its many pools of water (Welch 1881; fig. 4.15). In other areas of ECCC, the GLO descriptions range from "deep water course" (Lewis 1870, Oct.) along Kirker and Markley to "fine water," and "good water" (Day 1853, Aug.) along a tributary to Brushy Creek.

Unfortunately, the GLO survey does not comprehensively cover creeks in the study area, and many of the data points we do have are from 1853, an unusually wet year (see fig. 3.14). The earliest comprehensive source that shows dry season flow patterns is the early USGS mapping. Historical USGS quads (1896-1918) show 47 miles of perennial stream reaches in the study area, representing about 10% of total stream length. These reaches occurred along Kirker Creek and tributaries, Markley Canyon, Mount Diablo Creek and tributaries, Marsh Creek and tributaries (e.g., Sycamore Creek, Round Valley Creek, a tributary to Briones Creek), and Brushy Creek (fig. 4.16). While we have found USGS depictions of flow to be consistent with textual accounts on some large alluvial streams (e.g., Grossinger et al. 2008b), this source is not always accurate, and the extensive upland drainage network present in ECCC may result in less accurate mapping. Unfortunately, there is relatively little evidence in the historical record to verify the USGS mapping. As a result, although we present the USGS data here as a potentially valuable dataset, we did not use this information to depict flow on our historical habitat map (fig. 4.17).

Based on available data, we do feel confident that some streams contained reaches with flowing water and pools that lasted well into the dry season. Brushy Creek in particular is notable as a stream that was historically perennial over most of its length according to USGS, and was described with springs and pools by other sources. The stream flowed through an area with many springs in the hills before entering clay soils that would have helped the creek maintain its flow. In addition, along upper Marsh Creek a cluster of three quotes from June of 1853 describe summer flow: "fine water," "beautiful stream of running water," and "good water" (Day 1853; see fig. 4.17). In contrast, lower Marsh Creek flowed across a broad alluvial fan with loamy soils, and we do not find records of perennial flow or pools downstream of the present day Marsh Creek Reservoir.

Comparisons of GLO and USGS data with contemporary conditions suggest that some streams may have become drier over the historical period. In particular, portions of Kirker, Irish Canyon, and Marsh Creek were mapped as perennial by USGS and appear to be intermittent today. Other streams that were intermittent may now have perennial flow due to irrigation and urban runoff. More research would be needed to establish whether this apparent difference represents actual trends in flow over time.

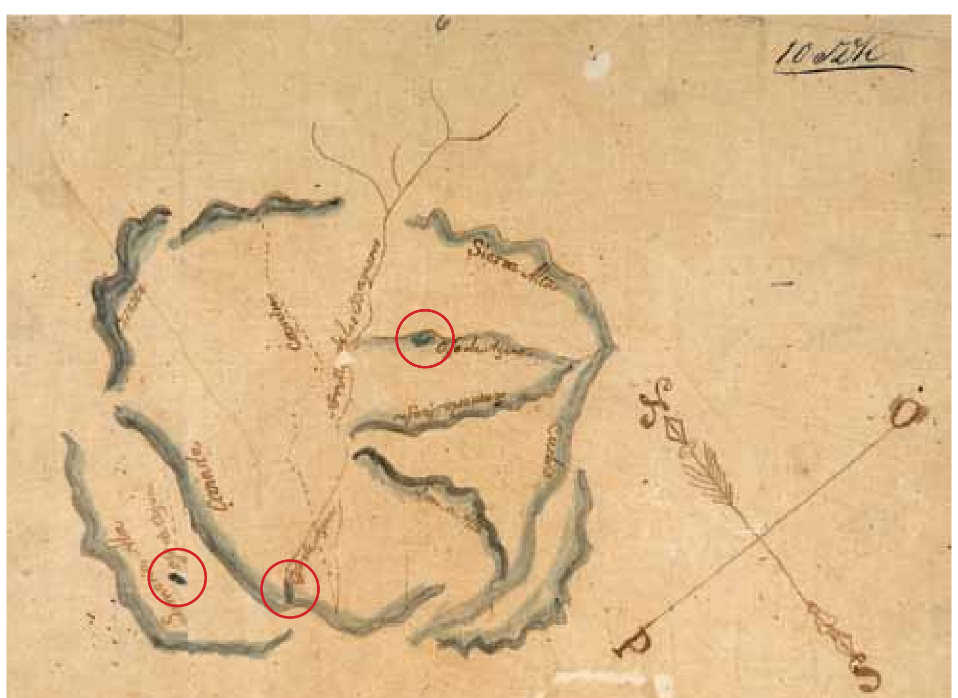


Figure 4.15. Pools at Los Vaqueros. (left) This ca. 1840 *diseño* shows three pools (circled in red on the map), labeled "ojo de agua." The thick blue lines represent the hills of ECCC, and the thin solid brown line down the center is Kellogg Creek ("Arroyo de los Vaqueros"). The dotted brown line represents an early road. Only one of the pools shown occurs along Los Vaqueros Creek. Although we could not locate these features from this map, the clear depiction of water sources on a map lacking in other detail emphasizes their importance to early settlers. (U.S. District Court, Northern District ca.1840b, courtesy of The Bancroft Library, UC Berkeley)

Figure 4.16. Historical intermittent and perennial flow by watershed, based on USGS data. (right) According to this source, upper Marsh Creek watershed supported the most extensive perennial reaches – over 20 miles – but other creeks also maintained several miles of perennial stream habitat. The chart shows flow by watershed rather than creek, so that "Brushy Creek watershed" includes all tributaries to Brushy Creek. Along the mainstem of Brushy Creek (as opposed to the overall watershed), 7 miles, or 82%, was perennial in USGS mapping.

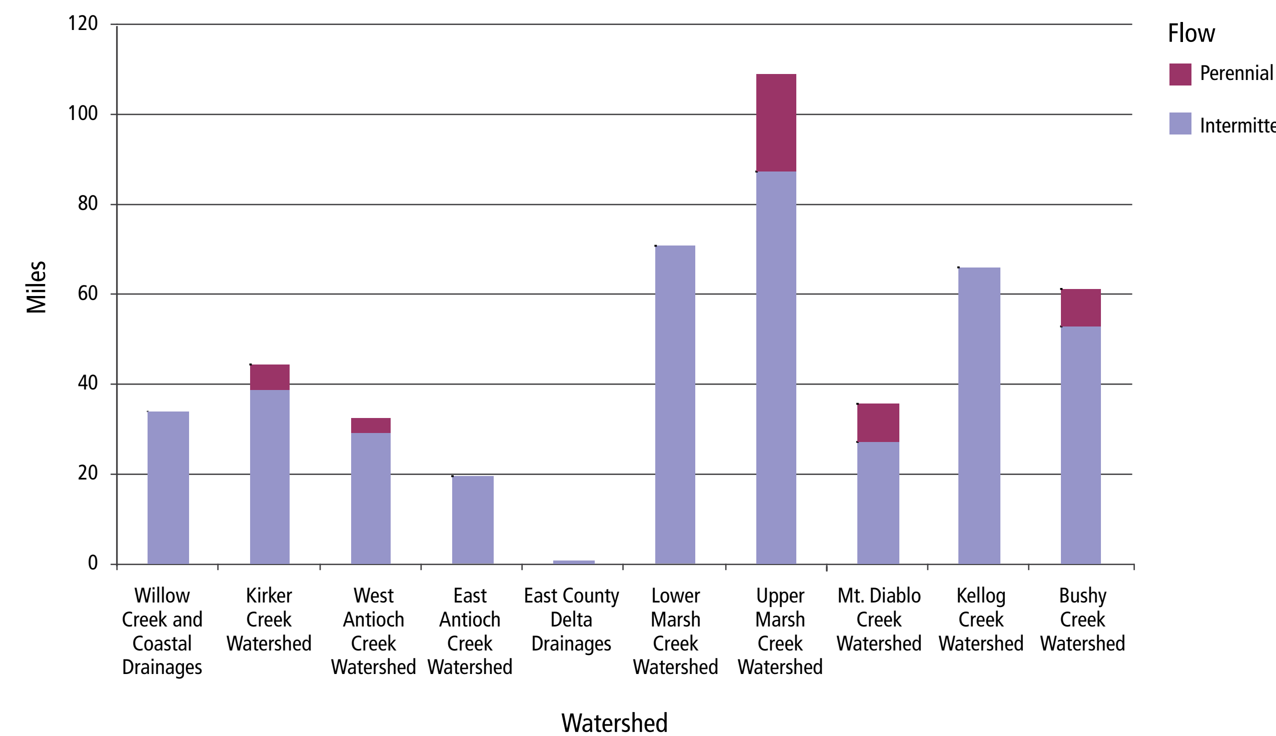


Figure 4.17. Dry season water. The figure below compares USGS and GLO data for perennial and intermittent stream reaches. Reaches mapped as perennial by USGS are coded with a solid blue line, while intermittent reaches are dashed. The table to the right presents all of the GLO data documenting pools, springs, and dry season flow. Although most of the GLO data presented is dry season data, we included quotes from the wet season if they documented springs, as these may have persisted into the dry season.

The GLO data is placed spatially on the map below: GLO data discussing dry season flow and pools are represented with light blue dots, while data supporting the presence of springs are represented with white and blue dots. The smaller dark blue dots represent springs documented by other sources. The points cluster in the northwest and southern portions of the study area. (GLO survey notes courtesy of the Bureau of Land Management)

Map #	Surveyor	Month/ Day	Year	Description
1	Sherman Day	Jul-25	1853	cross run 15 links wide, thicket of willows, buckeyes, good water [10 ft]
2	Sherman Day	Jul-23	1853	rocky gulch, fine water, pools, 25 links wide [16 ft]
3	Sherman Day	Aug-12	1853	fine running water, tulare valley, 20 links wide [13 ft]
4	Sherman Day	Aug-12	1853	alkali, no timber, buckeye, tulares, brackish
5	Sherman Day	Aug-12	1853	dry run 5 lks wide, spring [3 ft]
6	Sherman Day	Jul-21	1853	tulare spring
7	Sherman Day	Jul-21	1853	tulare spring
8	Sherman Day	Jul-21	1853	tulare spring
9	Sherman Day	Jul-21	1853	water in valley, few oaks and buckeye bushes at head of run
10	Sherman Day	Jul-22	1853	run 0.5 chain wide, excellent water, white oak [33 ft]
11	Sherman Day	June-27	1853	fine water 15 links wide [10 ft]
12	Sherman Day	June-28	1853	grove of young oaks, running branch, good water, 20 links wide [13 ft]
13	Sherman Day	June-29	1853	scrub white oak, thickets, chaparral, clear running stream 20 links wide, bushy live oak [13 ft]
14	Sherman Day	Jul-21	1853	tulare run, good water, 10 links wide [7 ft]
15	Sherman Day	Jul-21	1853	tulare spring 30 links wide [20 ft]
16	John C. Partridge	Jan-26	1873	spring water
17	Sherman Day	Jul-20	1853	creek, pool, big oak
18	John C. Partridge	Jan-24	1873	spring 80 links distant [53 ft]
19	John C. Partridge	Jan-20	1873	spring E 75 links [50 ft]
20	John C. Partridge	Jan-23	1873	spring brook 3 links wide [4 ft]
21	Sherman Day	Jul-20	1853	white oak, water, creek, pools
22	Sherman Day	June-8	1853	stream of running water 15 links wide [10 ft]
23	John C. Partridge	Jan-09	1873	spring brook, 6 links [4 ft]
24	G. H. Thompson	Feb-1	1867	2 chs west of large soda spring [132 ft]
25	William J. Lewis	Oct-9	1870	deep water course, Hughe's house 300 links [198 ft]
26	William J. Lewis	Oct-11	1870	ravine, deep water
27	William J. Lewis	Oct-7	1870	running stream, 60 links wide [40 ft]
28	William J. Lewis	Oct-12	1870	deep water course 100 links wide [66 ft]
29	William J. Lewis	Oct-12	1870	deep water, 60 links wide [40 ft]
30	William J. Lewis	Nov-29	1860	cross spring at head
31	William J. Lewis	Dec-1	1860	cross spring brook
32	William J. Lewis	Nov-30	1860	cross spring branch, Quin's house
33	William J. Lewis	Dec-1	1860	spring branch, 10 links wide [7 ft]
34	William J. Lewis	Sep-25	1870	deep water course, small stream 20 links [13 ft]

Riparian Analysis

Aerial Analysis: 1939 to 2005

Between 1939 and 2005, all creeks except for Marsh Creek showed an increase in summed length of closed, open, and sparse tree cover, with a related decrease in miles with herbaceous cover (fig. 4.18). In contrast, along Marsh Creek overall length of low/no cover reaches increased from 16% to 20% of total length, while summed length of closed, open, and sparse tree cover remained roughly the same (84% to 80%). On Marsh Creek, tree cover became more dense overall: closed canopy cover increased from 25% to 45%, while open canopy and sparse canopy cover dropped from 47% to 24% and 12% to 11% respectively. Some creeks experienced an increase in length of channel going underground (in urban areas) or passing through reservoirs (e.g., Kellogg Creek; fig. 4.19). The shift towards higher density tree cover is likely due to increased flow in many streams due to urban runoff , irrigation, or other water management practices.

Grouping the streams by geomorphic unit reveals that changes in cover type since 1939 also differed significantly by elevation. That is, although all creeks except Marsh have an overall trend of greater summed length of closed, open, and sparse tree cover in 2005 compared to 1939, virtually all of this change has occurred in the plains (fig. 4.20). For reaches within the plains, low/no cover characterized 74% of the total length in 1939, but only 43% by 2005. Conversely, in 1939 the three tree cover classes together comprised 24% of the length in this region and doubled to 48% by 2005. In the foothill region, total length of all tree cover types has not changed significantly and herbaceous cover has dropped from 42% to 36% of total length. However, the proportion of closed, open, and sparse cover has shifted towards more dense cover. This is demonstrated in the shift in open canopy cover, which characterized 31% of the total length in 1939 but only 21% in 2005, while closed canopy increased from 5% to 15% of the total length. The montane region has experienced a similar shift toward denser cover, though the percent of low/no cover has remained the same.

The density of riparian tree cover differed by geomorphic unit as well. For example, over 50% of montane region streams were characterized by closed canopy riparian for both years. This contrasts with other regions, where closed canopy cover comprised less than 20% of total stream length.

Within the Marsh Creek watershed, this difference across geomorphic units is quite clear. As might be expected, in the montane region Marsh Creek has a much higher percentage of tree cover compared to the foothills or plains. One of the more dramatic changes over time has occurred along the foothill reaches of Marsh Creek. We found that open canopy cover decreased from 73% of the total length within the this region to 37% (fig. 4.21).

Pre-1939 Evidence for Riparian Characteristics

Riparian cover shown in 1939 imagery may not be representative of earlier conditions. To investigate riparian characteristics prior to 1939, we drew on GLO surveys, photographs, and a variety of textual sources. As in the aerial photography analysis, we found a pattern of variation in cover type between geomorphic units.

The GLO survey record provides details about riparian tree distribution and species composition from the 1850s through the 1870s. In this region there were no records of GLO surveyors entering or exiting a substantial riparian corridor. However, surveyors did record individual trees close to creek channels, allowing us to extract some information about riparian tree species composition. Thirty-nine GLO trees fell within 160 ft of historical creek channels (see p. 29). Two of these were sycamores (both along tributaries to upper Marsh Creek), while the remaining 37 were live oaks, 'white' (presumably blue or valley) oaks, 'red' (blue/valley) oaks, and undifferentiated 'oaks' (fig. 4.22). (Six buckeyes and five additional sycamores were also noted in the study area but outside of our 160 foot riparian buffer.) The distribution of these riparian trees reflects our geomorphic unit divisions, with fewer streamside trees recorded (almost all of which are blue or valley oak) on the plains, and more trees (including live oak and sycamore) in the upland regions (fig. 4.23).

The lowland riparian corridor appears to have been dominated by oaks. The best early images of riparian vegetation in East Contra Costa County come from the oblique aerials taken by George Russell ca. 1925. These show a mature narrow corridor of large oaks along lower Marsh Creek (fig. 4.24), as recorded in GLO data. While other species were undoubtedly present as minor components, an oak-dominated riparian corridor would be consistent with the likely intermittent flow conditions (see Grossinger et al. 2006, 2008a). These images do not show any remnant patches of broad riparian forest like those found along other Bay Area streams at similar phases of agricultural development (e.g., Napa River, Santa Clara River; see Grossinger et al. 2008b, Grossinger and Askevold in press), suggesting that riparian cover may have been more limited in extent here.

Narrative accounts reaffirm the general pattern of sparse tree cover and oak-dominated riparian zones in the plains, with more dense riparian cover in the hills. In the uplands, historically as today, there is evidence for a dense, mixed riparian zone: "Mount Diablo, down whose slopes come shady rivulets that prattle through the densely foliaged canons" (History of Contra Costa County 1882). This contrasted with more open riparian structure on the plains: the "belt of fine old oaks that grew on the delta of Kellogg Creek was a conspicuous landmark, for the reason that it was the first bunch of timber found...[in]...a distance of two hundred miles" moving north (Dean in Hulaniski 1917).

Research is complicated by the fact that many of the historical records tend to be generalized or are themselves historical reconstructions. For example, an 1882 county history described conditions 30 years prior in 1849: "cheered by the evergreen oaks on the Marsh creek, the lighter green cotton-wood, and the occasional glimpse among the thick foliage of a running stream..." (History of Contra Costa County 1882). Another classic county history gave a detailed description of riparian cover in Contra Costa County: "All the valleys are traversed by water courses, whose banks are fringed with trees and shrubs. Laurel, live oaks, buckeyes, Manzanita, alders, willows, and the ash, are the principal trees" (Smith and Elliott 1879). Unfortunately, the exact text also appears in their description of Napa County one year earlier (Smith and Elliott 1878), which itself is copied from text by Menefee (1873). This detailed description may not be locally specific.

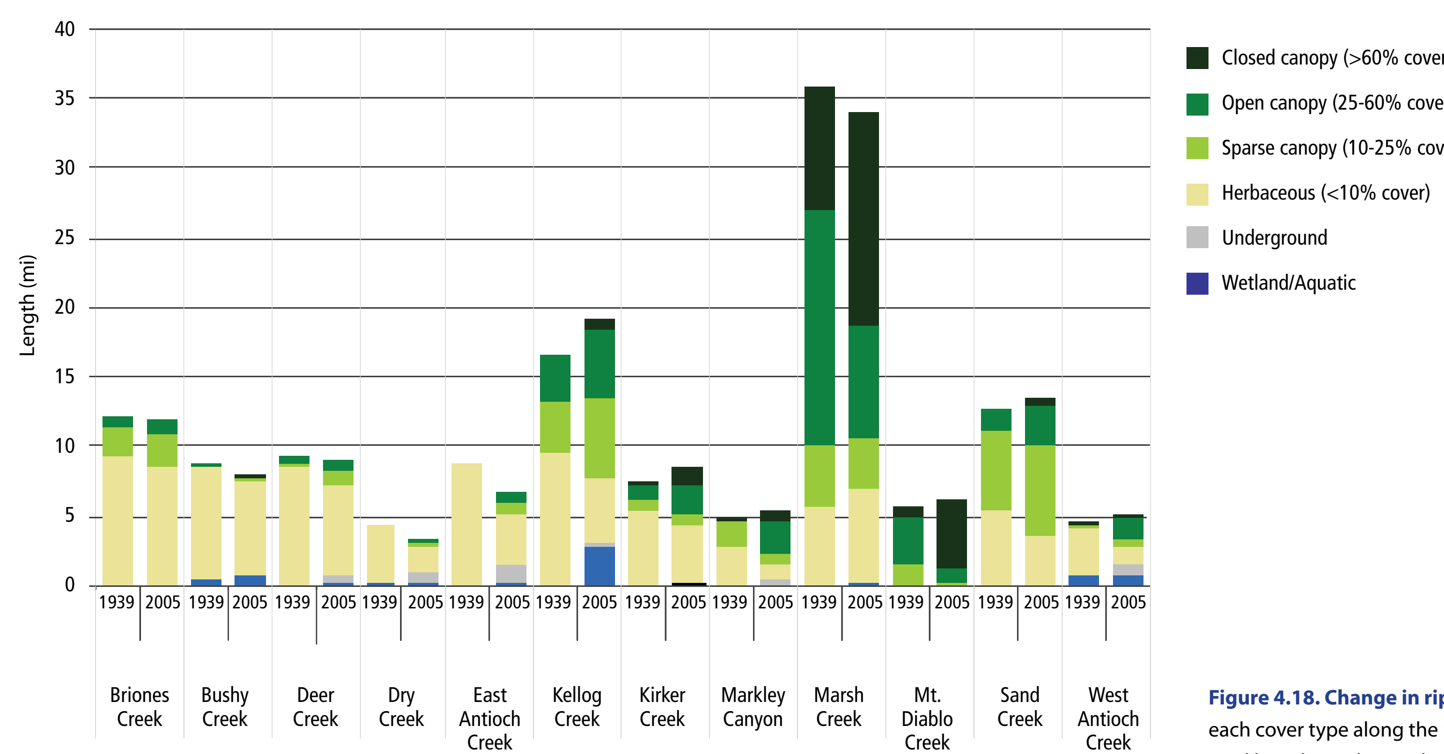


Figure 4.18. Change in riparian cover by creek. This graph compares miles of each cover type along the mainstems of the major creeks of ECCC. Differences in total length are due to changes in the drainage network.

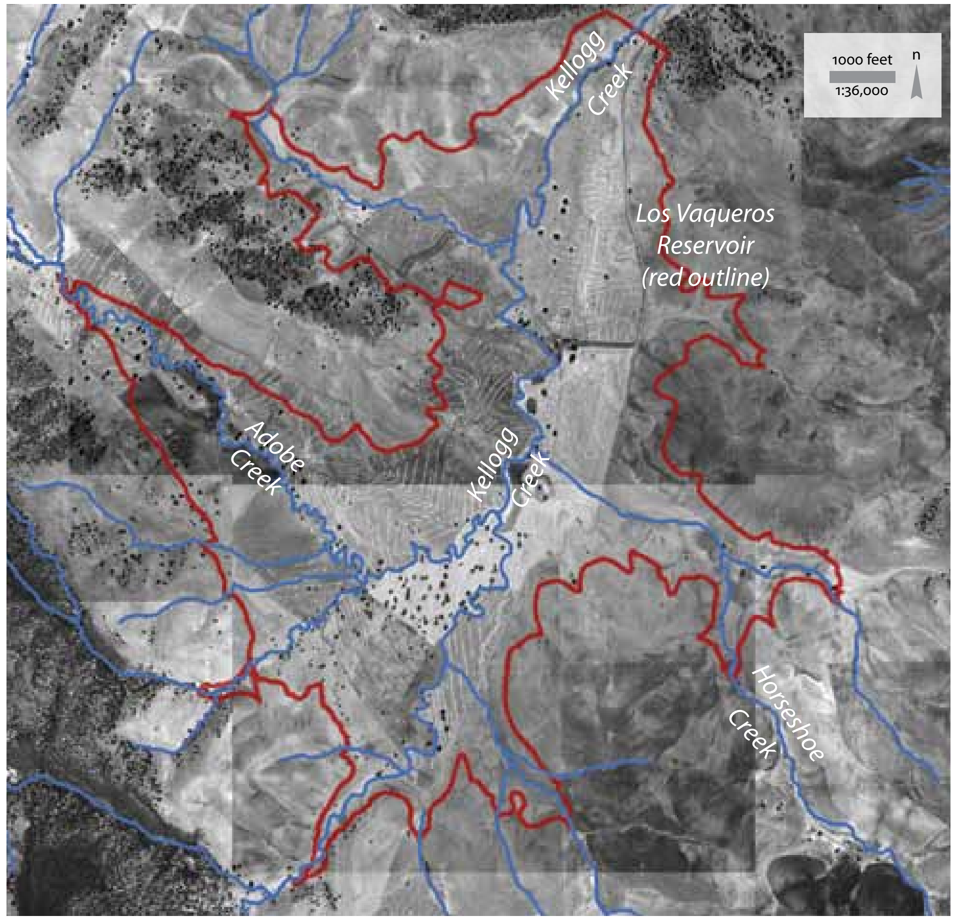


Figure 4.19. Historical riparian cover along Kellogg Creek. Some historical riparian trees have been covered by new wetlands and reservoirs. The creation of Los Vaqueros Reservoir provides the most dramatic example of this. The historical aerial photograph captures the region before the reservoir was built; contrast with the contemporary aerial shown at the bottom of the page, overlaid with the historical streams map. At bottom, an image of Los Vaqueros reservoir today. (Top: USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; Bottom: February 28, 2004, by Scott Hein, www.heinphoto.com)

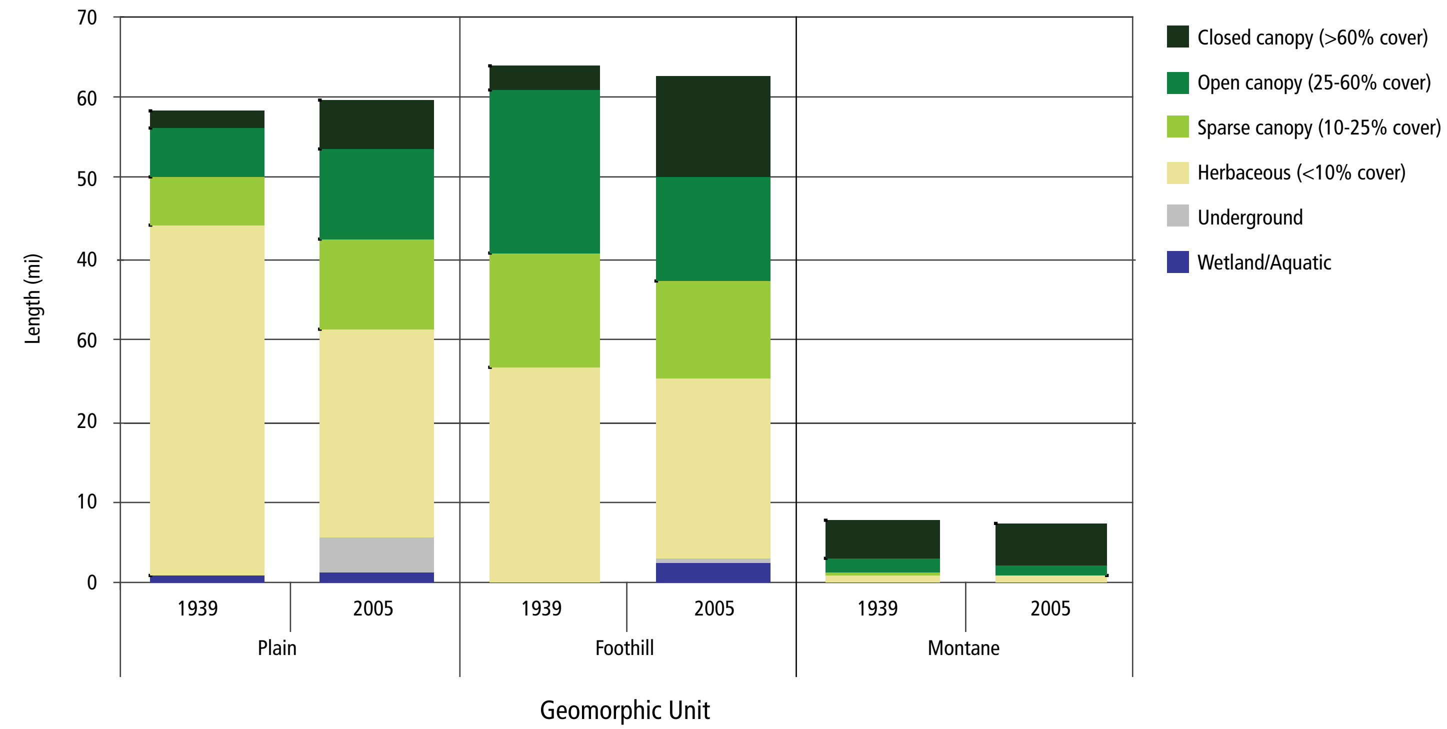


Figure 4.20. Change in riparian cover by geomorphic unit. (above) Each column shows the summed length of each riparian cover type along major reaches in ECCC divided by geomorphic unit. The geomorphic units are plain (<200 ft), foothill (200-900 ft), and montane (>900 ft). Again, differences in total length between 1939 and 2005 are due to changes in the drainage network.

Figure 4.21. Increase in contemporary riparian cover density along Marsh Creek. The shift towards more dense cover can clearly be seen in this stretch of Marsh Creek along Marsh Creek Road, 7 miles west of Walnut Boulevard. The 1939 open canopy cover has become closed canopy cover by 2005. (Left: USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; Right: USDA 2005, courtesy of NAIP)

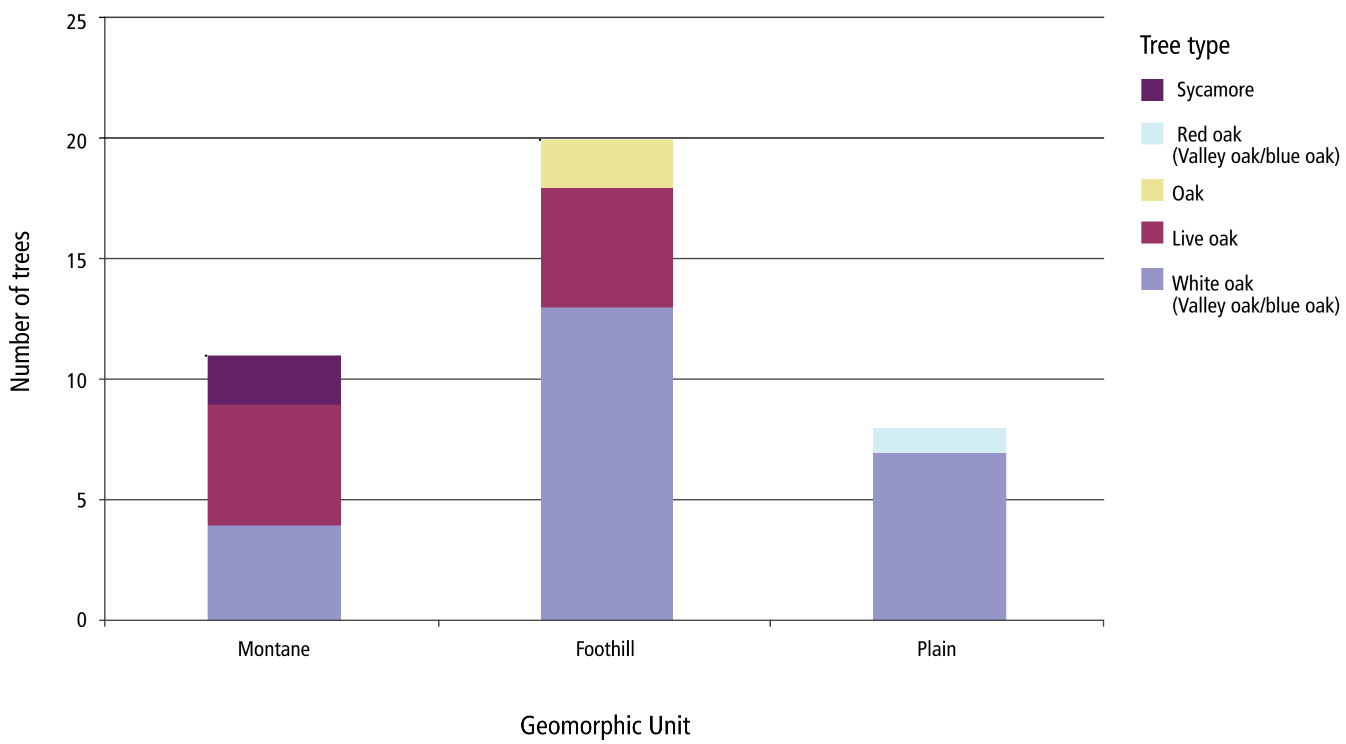


Figure 4.22. GLO riparian trees by geomorphic unit. (above) These data show bearing trees recorded by the GLO survey from the 1850s-1870s. While 'white oaks' (likely blue or valley oaks) were distributed on creeks throughout the study area, sycamores and live oaks were found only in the upper, more hilly and perennial reaches. All of the species recorded along foothill and plains creeks were oaks.

Figure 4.23. "Picnic on Marsh Creek." This view of Marsh Creek shows shallow summer flow and fringing alders. (Unknown ca. 1890, courtesy of the East Contra Costa Historical Society)

Figure 4.24. Historical riparian cover along lower Marsh Creek. This ca. 1925 aerial view of lower Marsh Creek shows a sinuous narrow corridor of large oaks. Individual oak trees can be seen growing along the banks of the channel. Most trees visible in this image are arranged in a narrow corridor along the creek, although a few remnant oaks spread slightly further from the stream banks. In contrast to other Bay Area streams, no remnant patches of broad riparian cover were visible along Marsh Creek. (Russell ca. 1925, courtesy of the State Lands Commission)

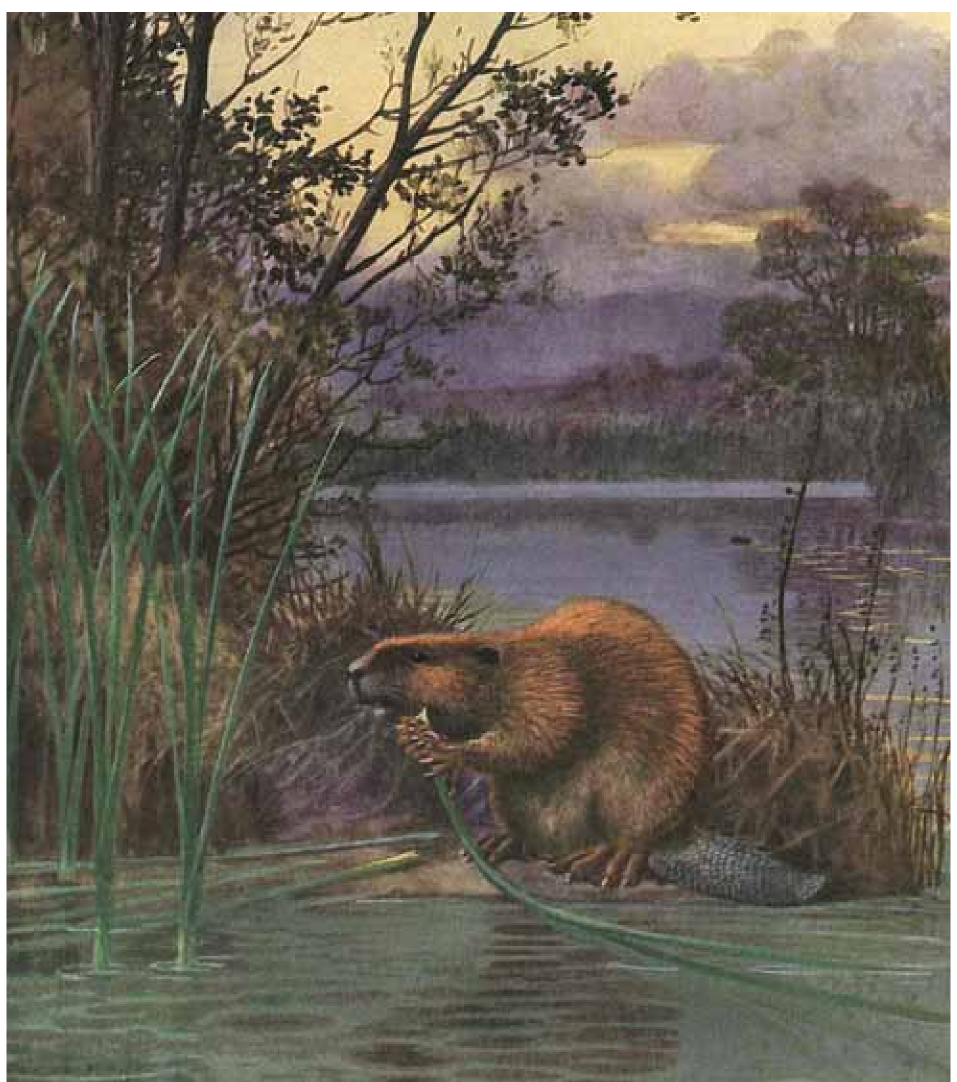
Historical Presence of Beaver

The potential historical presence of beavers on local streams can significantly impact our understanding of natural fluvial functions and habitats (fig. 4.25). Establishing historical beaver presence is particularly relevant in Contra Costa County, where the species has recently established on Alhambra Creek. However, the historical distribution and abundance of beaver in the Bay Area is not well documented. Grinnell et al. (1937) excluded Bay Area creeks in his estimate of historical statewide distribution. The earliest descriptions, by Spanish explorers, rarely took note of beavers. The trappers themselves only rarely documented their daily activities; some early journals were also lost (Maloney 1943a). By the time many of the more descriptive American journals were produced, after 1840, California had been extensively trapped.

Specific evidence for the Bay Area includes Hudson's Bay Company accounts in 1832-33, in the journals of John Work and others. These accounts confirm the general presence of beaver in the Delta and North Bay streams, although they do not appear to have visited Contra Costa County. However, in 1832 the Work expedition camped and trapped at the "mouth of the Sacramento [River] opposite Pittsburg" (Maloney 1943b). They caught two beaver, which confirms the presence of beavers in the marshes of the Pittsburg-Antioch-Suisun shoreline. Work was disappointed in the North Bay streams, which he had visited because those areas were thought to be untouched. He did report some beaver in the Napa River, Sonoma Creek, and Petaluma River watersheds. Skinner (1962) also stated that beaver were historically present at least in Napa River, Sonoma Creek, and Santa Clara County's Coyote Creek. Beaver were also common in the Delta (Maloney 1943b, Skinner 1962).

In the course of the expedition, Work gave several explanations for why many coastal systems seemed to have disappointing quantities of beaver, or none at all. In particular, he noted that while the streams had substantial water in the spring, they may not have had sufficient water in the dry season for beaver or were simply too small. In the Russian River, dense Native settlement was speculated to have reduced the number of beaver.

The above information suggests that beaver may have been present at advantageous sites in ECCC, such as along the perennial reaches of larger creeks. There is some anecdotal evidence of beaver in the far eastern part of Contra Costa, near Byron: "there was one lone sycamore, I have been told, which stood in the area of the old Hoffman place. I understand from a member of the family, that she remembers her father speaking of a tree, a lone tree, out of its element, that had been felled by beavers" (Hill 1990). However, it is difficult to find corroborating evidence. Many stream reaches in Contra Costa County were probably not suitable for beaver because of their small size, intermittent nature, and limited amount of preferred forage (e.g., willows, cottonwoods; Johnson and Harris 1988-1990).



In the mean time I will proceed on to the bay & see if there are any beaver to be had along the North side of it which is not known to have been trapped or even visited by any parties of hunters yet.

—WORK IN MALONEY 1945

Figure 4.25. American beaver. Painting from *Fur-bearing mammals of California* (Grinnell et al. 1937), © 1965 by the Regents of the University of California. (Reprinted by permission of UC Press)

DISCUSSION

This section discusses the implications of changes to the stream and riparian systems of ECCC. Building on the historical data presented in the previous chapters, this section discusses important historical resources, restoration potential, and historical fish assemblages.

Transformation of the Drainage Network

The total miles of channel length lost and gained in the historical period are fairly equivalent, so that the overall length of the drainage network has not changed substantially. Most change has been change in channel form. The historical channel length that has been lost was largely composed of branching, discontinuous segments that carried water only in times of high flow. Rather than connecting to another stream or the tidal marsh, many creeks spread across broad floodplains, dispersed into wetlands, and sank into alluvial soils, recharging groundwater. In many cases, the point at which streams distributed may have varied annually, depending on rainfall. Often these streams caused significant flooding problems for farmers and settlers attempting to live in the plains (Eastern Contra Costa Soil Conservation District et al. 1959; fig. 4.26).

Today these diffuse drainages have been largely replaced by more well defined, straightened, continuous channels (see fig. 4.6). Most of the modification to the drainage network has occurred in the plains, much of it to control flooding (see Contra Costa County Department of Conservation and Development 2003). The contemporary courses of these discontinuous creeks have been altered to route them directly to the San Joaquin River or other streams. Sand, Kellogg, and Marsh creeks are good examples of drainages that have been heavily modified in their lower reaches. As in other watersheds, the expansion of the channelized drainage network has the potential effect of increasing peak flows downstream, with potential negative effects for flooding, bank erosion, and storm water quality, as well as for any vegetation and animal life associated with the stream (e.g., Grossinger et al. 2006).

Pools and Perennial Reaches

Historically, perennial wetlands were relatively rare in ECCC and thus were of extremely high value to the many species dependent on dry season aquatic resources (see Chapter 5). Perennial stream reaches and summer pools contributed significantly to this resource. We found records indicating summer pools and water, especially in the southern portion of the study area. (See p. 69 for discussion of how this may have helped to support red-legged frogs historically.)

Today perennial stream reaches occur along Marsh, Kirker, Donner, and lower Sand and Deer creeks (Jones & Stokes 2006), most of which were likely intermittent historically. This increase in perennial reaches is likely due to irrigation and urban water inputs (Jones & Stokes 2006, see also Cain et al. 2003).

The substantial record of historical natural pools in certain watersheds may suggest greater potential for in-stream habitat in those areas than currently exists. Further research to establish the contemporary presence or absence of pools along otherwise intermittent Kellogg, Frisk, and Brushy creeks could help explain the hydrology of the region and suggest reaches for enhancement.

Riparian Cover

Our comparison between 1939 and 2005 suggests that low/no tree cover and open canopy cover riparian systems were more common in the early 20th century than today, at least in the foothills and valley plains. This low density vegetation is consistent with the arid climate and resulting intermittent and ephemeral streams of ECCC. While not well-recognized as part of the natural riparian "palette," more open riparian structure has been observed historically in Mediterranean systems in California and elsewhere (Kondolf 2001; Grossinger et al. 2006, 2008a).

Overall we found more closed canopy cover in 2005 than in 1939. This trend to overall denser cover may be attributable to the fact that some stream reaches are kept wetter today than they were historically due to dams (e.g., upstream of Marsh Creek Reservoir) or a higher water table as a result of urban runoff. Similar riparian expansion due to artificial flow inputs has been observed on other Western streams (White and Greer 2006). Such changes can potentially have beneficial effects, providing increased aquatic habitat, or negative effects (e.g., riparian conversion, habitat for non-native predators).

Dense riparian tree cover was found in the foothill and montane regions for both time periods, and is presumably associated with spring-fed reaches. Fewer hydrologic and land use changes in the montane region have likely contributed to the more stable cover type proportions over the past 70 years, making these reaches more representative of historical conditions (fig. 4.27). Patterns in riparian structure are consistent with geomorphic units, suggesting that larger physical characteristics (e.g., groundwater depth) are likely controlling these differences.

There were no records of willow-cottonwood forests or *sausals* within the study area. These dense willow swamps were features of many of the nearby watersheds, including Napa River, Guadalupe River, Alameda Creek, and Stevens Creek (Grossinger et al. 2006, Beller et al. 2010, Grossinger et al. forthcoming, Stanford et al. forthcoming). Their absence in ECCC is likely due to topography – all of these systems include confined valleys that supported springs.

While our comparison between 1939 and 2005 riparian conditions suggests that the system has shifted toward denser riparian cover today, 1939 conditions already reflect decades of Euro-American activity. Though we lack reliable data from the 1800s, the 1930s may have been a low point in riparian cover. This hypothesis may apply particularly in the foothills and plains where plowing and stream incision due to wheat farming may have had significant impacts (Adams pers. comm.). If so, the increase in riparian tree cover density in some locations could represent recovery to more closely approximate historical conditions (e.g., Leopold 1994, Brierley et al. 1999). We should also stress that, while our analysis of riparian cover shows overall trends, local changes must also be understood and might, in some cases, be different from the larger trend for a particular mainstem.

Protection and restoration of riparian habitat is a major focus for the HCP (Jones & Stokes 2006). While we find no overall declines in riparian tree cover since 1939, some change may have occurred prior to this. Even between 1939 and 2005, certain reaches (particularly lower reaches of creeks) have experienced local-scale loss of riparian trees. The most important change may not be in the overall amount of cover, but in the types and functions of riparian corridors. Because of alterations to stream courses and hydrology, the composition and architecture of native riparian corridors has been substantially altered. Restoration strategies should focus on the target types and characteristics of riparian corridors, rather than simply quantity.

Historical evidence suggests that appropriate restoration targets also likely vary through the study area (i.e., by geomorphic unit). In some cases changes in hydrology may have created conditions that would no longer sustain the historical

Figure 4.26. Marsh Creek floodwaters at Knightsen. This 1952 photo shows extreme flooding of the alluvial fan of Marsh Creek. This photo was taken shortly before the beginning of Marsh Creek flood control efforts, such as those shown in figure 4.11. This photo was taken at the submerged intersection of the railroad and Delta Road. (Contra Costa County Flood Control 1952, courtesy of Contra Costa County)

Figure 4.27. "Marsh Creek Country." In this historical photo, the riparian corridor of Marsh Creek is constrained to a small fringe near the creek by Marsh Creek Road and the agricultural fields at right. (Unknown n.d., courtesy of the East Contra Costa Historical Society)

Marsh Creek has attained its highest mark since 1884, flooding the entire iron-house section and filing in the adjoining tule lands. District 107, from Marsh Landing up, and the entire Jersey tract, together with all other tule lands in Contra Costa county, are submerged, destroying large areas of alfalfa and preventing the cultivation of the land for the present season.

—*SACRAMENTO DAILY RECORD-UNION* 1890

riparian cover and other sites may actually provide more useful conceptual models. However, in other places historical riparian structure may still be well adapted to local conditions.

We did not analyze changes by reach, so our findings do not describe some of the local changes that have taken place. The historical dataset provides a starting point for more detailed examination of specific reaches of interest to evaluate restoration approaches. In general, our findings indicate that a relatively sparse, oak-dominated corridor may be the most appropriate riparian cover for restoration over much of the plains region.

Contemporary Reservoirs and Stock Ponds

In addition to the many straightened and channelized stream segments in ECCC, the 31 water treatment ponds and reservoirs and 407 ponds mapped for the HCP (Jones & Stokes 2006) have undoubtedly changed local hydrology (see p. 65). In some cases stock ponds have become important as a source of water for native species such as California red-legged frogs.

Dams on stock ponds and reservoirs can impact temperature, fish passage, sediment transport, water quality, and flow regimes, generally reducing peak flows (Ligon et al. 1995, Gasith and Resh 1999). The combination of sediment trapped upstream of the reservoir and smaller peak flows downstream of the reservoir can result in channel incision and reduced channel migration, or a change in floodplain characteristics and the type of sediment deposited in the channel (Ligon et al. 1995, Shields et al. 2000).

In ECCC, stock ponds and reservoirs create a network of dams across drainages, altering flow patterns. For example, runoff from the upper watershed of Marsh Creek is entirely captured by the Marsh Creek Reservoir (Cain et al. 2004). Creek behavior and the composition and extent of riparian habitat have changed over the last two centuries as the result of these modifications. Management strategies for downstream reaches will need to consider these effects.

Role of Semi-Arid Streams

Although we have emphasized the importance of pools and perennial reaches as habitats for this region, the more widespread intermittent streams and grassland riparian zones found historically are also an important part of ECCC. This type of riparian cover contrasts with historical conditions in larger sycamore-dominated, intermittent South Bay systems (Grossinger et al. 2006, 2008a) and with other lowland streams with more rainfall (e.g., lower Napa River, lower Wildcat Creek). Native species in ECCC had adapted to xeric conditions: riparian zones dominated by relatively low density, drought-tolerant oaks could thrive on intermittent streams with low rainfall.

The historical characteristics of ECCC streams may provide a model for adaptation to the increasingly arid conditions anticipated with climate change (Cayan et al. 2009, Cloern et al. 2011). The open, oak-dotted landscape and discontinuous, intermittent streams were functional xeric-adapted systems that can help us explore possibilities for adaptation to climate change.

Historical Condition of Marsh Creek

Recent research has recognized some of the major changes to lower Marsh Creek, and the concomitant loss of habitat complexity (Cain et al. 2003, 2004). The data compiled here extend our understanding of the system. Marsh Creek flows through a region with a Mediterranean climate, and was historically intermittent over much of its length. Historical evidence indicates seasonally innundated wet meadow habitats along lower Marsh Creek, as well as an extensive, sinuous secondary channel, which likely provided seasonally available off-channel habitat for salmonids. However, it does not appear that substantial perennial pools or perennial wetlands were found along lower Marsh Creek. Rather, we find that the lands near lower Marsh Creek were so dry that cattle could not water here in summer and depended for water on one large spring some distance away (Sibrian 1881).

Figure 4.28. Landscape painting of John Marsh's house. This landscape painting shows Marsh Creek meandering on the far side of John Marsh's house, crossing the image from left to right. The creek is surrounded by fairly dense riparian cover in this area, which is just downstream of a USGS-coded perennial reach. Mount Diablo is visible in the background, as are agricultural fields and scattered oaks. (Jump ca. 1865, courtesy of The Bancroft Library, UC Berkeley)

While Marsh Creek did overtop its banks and flood across the adjacent lands to the Delta during wet years, it flowed over sandy soils that likely provided relatively good drainage and did not develop into wetlands (*Sacramento Daily Record-Union* 1890, Carpenter and Cosby 1933). The riparian corridors were dominated by valley oaks tolerant of summer dry conditions that were likely restricted to the zone immediately surrounding the stream (fig. 4.28).

Unlike some other intermittent lowland creeks in the Bay Area (i.e., Grossinger et al. 2006, 2008a), Marsh Creek and other ECCC streams lacked multi-thread reaches covered with sycamores. In part this difference may be explained by the underlying geology, which likely supplied less coarse sediment. Many watersheds in the Bay Area are underlain by the highly erosive Franciscan Complex rocks, which generally produce large amounts of coarse sediment. In contrast, many ECCC streams drain watersheds underlain primarily by Great Valley Sequence rocks which are relatively fine-grained and do not supply the volume of coarse sediment that supports braided multi-thread reaches regionally.

The applicability of historical patterns in a heavily altered system such as Marsh Creek must be assessed in relation to current hydrology and geomorphic processes to identify viable restoration options. However, effective restoration will likely have to consider Marsh Creek's historical characteristics as a system adapted to low annual rainfall and little or no dry season surface flow, with riparian characteristics distinct from most other Bay Area streams. Historical conditions, such as the corridor of widely spaced valley oaks, suggest conceptual models that may be applicable to future xeric conditions likely with predicted climate changes.

Native Fish Assemblages

This section reconstructs probable native fish assemblages associated with major habitat types (table 4.1) using the historical evidence for habitat conditions and historical and recent records of fish in various watersheds (table 4.2). Streams, wetlands and other aquatic habitats within the watersheds of ECCC zoogeographically are part of the Sacramento-San Joaquin Fish Province (Moyle 2002). As such, these streams historically supported many of the species of freshwater and saltwater dispersant – as well as endemic – fishes found in the Central Valley and Delta. Historically, at least 19 native fishes likely characterized ECCC watersheds and their adjoining tidal marshes and slough channels, including Pacific lamprey, white sturgeon, green sturgeon, thicktail chub, hitch, California roach, Sacramento blackfish, Sacramento splittail, Sacramento pikeminnow, Sacramento sucker, Delta smelt, longfin smelt, Chinook salmon, rainbow trout/steelhead, threespine stickleback, prickly sculpin, Sacramento perch, tule perch, and starry flounder (fig 4.29; Ayres 1855, Gobalet 1992, Slotten et al. 1996, Moyle 2002, Gobalet 2004, Gobalet et al. 2004, Leidy et al. 2005, Leidy 2007, Slotten and Ayres 2009). Today the thicktail chub is extinct and the Sacramento perch has been extirpated from the study area. Currently viable steelhead populations are not known to occur in ECCC streams. However, steelhead stray into non-natal streams as a life history strategy. Therefore, it is possible that small numbers of steelhead periodically stray into ECCC streams, particularly larger watersheds such as Marsh Creek and Mount Diablo Creek.

Tidal Features

TIDAL SLOUGHS, TIDAL MARSH, AND TIDAL PONDS. Historically in ECCC, tidal habitats adjacent to Suisun Bay and the Sacramento-San Joaquin Delta contained the greatest diversity of native fishes (table 4.1). There were likely notable seasonal differences in the number of fish species using the various tidal habitats due to seasonal changes in water levels and the spatial arrangement between habitats. Tidal sloughs supported various combinations of fish species depending largely on local and regional environmental conditions, particularly the amount and timing of freshwater discharge through the Delta and its effect on water salinities, and the geographic location, configuration, accessibility, and size of slough habitats. Probable fishes associated with tidal sloughs included Pacific lamprey, white sturgeon, green sturgeon, thicktail chub, hitch, Sacramento blackfish, Sacramento splittail, Sacramento pikeminnow, Sacramento sucker, Delta smelt, longfin smelt, Chinook salmon, steelhead, threespine stickleback, prickly sculpin, Pacific staghorn sculpin, Sacramento perch, tule perch, and starry flounder (Moyle 2002). Sloughs likely functioned as migration corridors for adult Pacific lamprey and steelhead to suitable habitats in the perennial headwater reaches of Marsh Creek, although we found no historical records for the occurrence of either species in the watershed. Tidal sloughs were probably used by juvenile steelhead and Chinook salmon in conjunction with tidal marsh for rearing. Adult steelhead and Chinook immigrated through the Delta to spawning grounds in Central Valley streams and juveniles emigrated to the Pacific Ocean (Moyle 2002).

Tidal marsh supported similar but less diverse assemblages of native fishes compared to tidal channels, in part because dense marsh vegetation restricted access and movement of large-bodied fish species (e.g., sturgeon). Other pelagic fishes such as Delta smelt and longfin smelt would not be regularly expected to occur in densely vegetated tidal marshes. Juvenile steelhead and Chinook salmon likely used tidal marshes in conjunction with tidal sloughs for rearing.

In the northern ECCC, tidal ponds typically were embedded within dense tidal marsh vegetation, which restricted access by most fishes, and were characterized by intermittent, seasonal ponding. These ponds were typically covered by shallow, warm, high-salinity water relative to nearby tidal channels, although local environmental conditions were likely highly variable depending on the amount and timing of freshwater Delta outflows and tidal conditions. Tidal ponds probably supported juvenile Sacramento splittail and threespine stickleback (Herbold pers. comm.).

Stream and Related Features

LARGE PERENNIAL STREAMS. Historically, perennial streams were uncommon within the study area and were typically associated with areas of groundwater discharge from seeps and springs that were underlain by impervious formations such as bedrock or clay soils. Examples of potential large perennial stream reaches include mid- to upper-elevation Marsh, low- to mid-elevation Brushy, mid-elevation Kirker, and mid- to upper-elevation Mount Diablo creeks. Greater fish species diversity likely would be found in the mid-elevation reaches of large perennial streams (i.e., Marsh Creek) characterized by deep, permanent pools, compared to small, upper-elevation reaches (i.e., upper Marsh and Mount Diablo creeks). Archeological evidence from mid-elevation Marsh Creek near the John Marsh Historic Site confirms the presence of a diverse assemblage dominated by lowland forms (Gobalet 1992). Species collected from or likely to have occurred in perennial mainstem Marsh Creek before significant environmental modifications include thicktail chub, hitch, California roach, Sacramento blackfish, hardhead, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin, Sacramento perch, and tule perch (table 4.1; Gobalet 1992, Slotten et al. 1996, EBRPD 1997, Gobalet 2004, Leidy 2007, Slotten et al. 2009). Mid- to upper-elevation reaches of Mount Diablo and Marsh creeks likely contained suitable spawning and rearing habitat for steelhead and/or resident rainbow trout (Leidy et al. 2005, Leidy 2007). The perennial mainstem Marsh Creek fish assemblage is similar to that found historically in similarly situated lowland riverine environments within the Central Valley and tributaries to the San Francisco Bay estuary (Moyle 2002, Leidy 2007).

SMALL PERENNIAL STREAMS. Small perennial streams typically were likely restricted to the middle- to upper-headwater reaches of a few watersheds within ECCC. Small perennial streams would be characterized by shallow riffles interspersed by pools of small-to-moderate size and depth, cool summer water temperatures, and coarse sand-gravel-cobble-boulder substrates. Small perennial streams such as upper Mount Diablo and possibly upper Marsh creeks would function as spawning and rearing habitat for steelhead and/or resident rainbow trout. Potential small perennial stream reaches historically found on Marsh Creek and tributaries, Mount Diablo Creek and tributaries, and Brushy Creek likely supported fishes such as Pacific lamprey, hitch, California roach, Sacramento sucker, rainbow trout/steelhead, threespine stickleback, and prickly sculpin (table 4.1).

LARGE INTERMITTENT STREAMS. Intermittent reaches characterized by alluvial soils were often entirely dry by summer or fall. Under conditions where the stream reach completely dried, fishes would use intermittent reaches seasonally, particularly as a migration corridor to other suitable intermittent or perennial habitats with year-round pools found within the watershed. For example, while lower Marsh Creek likely dried completely, fish that migrated through this intermittent reach could persist in upstream perennial reaches. Fish assemblages in intermittent streams would be highly variable depending on local environmental conditions. Generally, intermittent streams with large, deep, permanent pools would be expected to support greater fish species diversity than reaches with small pools. Fishes likely associated with large intermittent streams such as the lower and mid-elevation mainstem reaches of Marsh Creek include Pacific lamprey, thicktail chub, hitch, California roach, Sacramento blackfish, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, prickly sculpin, tule perch, and Sacramento perch (table 4.1). Steelhead adults and smolts possibly utilized intermittent reaches of Marsh Creek as a migration corridor to suitable perennial habitats.

SMALL INTERMITTENT STREAMS. Historically, small streams with intermittent mainstem reaches descended from the foothills (e.g., Willow and West and East Antioch creeks), or formed tributaries that seasonally connected to larger tributaries or mainstem streams (e.g., Sand and Deer creeks). The smallest streams flowed for only short periods and were likely fishless. Small, intermittent tributary creeks that maintained permanent pools embedded in otherwise summer-dry stream reaches would most likely contain hitch, California roach, Sacramento sucker, and threespine stickleback (table 4.1).

DISCONTINUOUS STREAMS AND DISTRIBUTARIES. The lower reaches of most streams within ECCC descended from the foothills in defined channels before dissipating into undefined or multiple small channels on their alluvial fans (see fig. 4.3). Small tributary intermittent streams and distributaries that rarely or never had surface connections with tidal wetlands were probably fishless. However, many discontinuous streams likely maintained seasonal surface hydrologic connections with tidal wetlands or large intermittent or perennial streams during periods of flooding, and these connections would allow fish to colonize the upper reaches of streams with suitable habitat. Discontinuous streams and distributaries with only intermittent connections to downstream waters may have supported fishes such as hitch, California roach, Sacramento sucker, and threespine stickleback, 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, R. Leidy, pers. observ.).

Palustrine Wetland

SPRINGS AND SEEPS. Springs and seeps were geographically widespread throughout ECCC and were characterized by shallow subsurface to surface water saturation, and/or small permanent pools with variable discharges. Seeps were fishless but were likely critical in supporting native fishes through the discharge of cool groundwater into summer pools embedded within otherwise summer-dry stream reaches. Springs were also likely fishless, however, perennial springs with surface hydrologic connections to other permanent aquatic and wetland habitats could have been colonized by fishes such as California roach and threespine stickleback. For example, Byron Hot Springs within the Brushy Creek watershed was characterized by a mosaic of interconnected alkali wetlands, ponds, and springs that could have contained fish.

WET MEADOW. Wet meadows were seasonally flooded herbaceous wetland communities often adjoining tidal marshes that occurred primarily within the northern portion of ECCC. Wet meadows would typically be fishless. However, following periods of moderate to high seasonal precipitation and flooding it would be possible for fish to enter inundated wet meadows from adjoining streams and tidal marsh habitats. As such, wet meadows may have functioned to connect otherwise discontinuous streams with tidal marsh, thereby allowing for colonization of some streams by fishes, such as hitch, California roach, prickly sculpin, and threespine stickleback. It is possible that Sacramento splittail would move seasonally onto wet meadow floodplains bordering tidal marsh to feed (Moyle 2002). The importance of floodplain wetlands to the movement of small fishes between watersheds has been documented for streams tributary to the San Francisco Bay estuary (Snyder 1905, Leidy 2007).

PERENNIAL VALLEY FRESHWATER MARSH, PERENNIAL PONDS, SEASONAL PONDS. Perennial and seasonal freshwater ponds were typically associated with valley freshwater marsh. Perennial freshwater marsh and large ponds with seasonal surface water connections to larger perennial streams or tidal marsh likely supported fishes such as Sacramento blackfish, hitch, Sacramento splittail, thicktail chub, Sacramento pikeminnow, Sacramento sucker, threespine stickleback, Sacramento perch, and tule perch. Perennial freshwater marsh and ponds embedded within grassland landscapes with no surface water connections to other permanent aquatic features were likely fishless. As with alkali wetlands and ponds, 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, and therefore would be an important determinate of fish assemblage membership and distribution.

Alkali Wetland

ALKALI PERENNIAL POND, MARSH, FLAT, SINK SCRUB, AND MEADOW. Alkali wetlands formed a complex landscape mosaic of interconnected habitats characterized by highly variable hydrologic conditions. For example, Brushy and Frisk creeks flowed through a largely continuous gradient of seasonally and permanently flooded alkali wetland habitats. These features included alkali pond, marsh, flat, sink scrub, and meadow that eventually connected with tidal marshes in the Delta. Many of these wetland features were characterized by seasonal surface water connections, especially during extremely wet periods when the combination of high tides and discharges from local watersheds and through the Delta would cause extensive flooding. The aerial extent of flooding and the persistence of ponded water would vary from year to year depending on regional and local precipitation, which in turn would affect fish colonization and assemblage membership and distribution. Under conditions of rapidly receding waters some fish could be trapped in temporary wetlands and ponds. Perennial ponds and marsh would likely contain alkali tolerant fishes such as hitch, California roach, threespine stickleback, and depending on size and location possibly Sacramento perch and tule perch.

Figure 4.29. Sacramento sucker *(Catostomus occidentalis)* collected along lower Marsh Creek in 1981. (Photo by Robert Leidy)

Table 4.1. Historical wetland habitats and associated probable fish assemblages.

Habitats	Example(s) (with relevant illustrations)	Probable Native Fish Assemblage[1]	Notes on Habitat Use
TIDAL FEATURES			
Tidal slough	Tidal sloughs bordering Suisun Bay and the Sacramento-San Joaquin Delta	Pacific lamprey, white sturgeon, green sturgeon, thicktail chub, hitch, Sacramento blackfish, Sacramento splittail, Sacramento pikeminnow, Sacramento sucker, Delta smelt, longfin smelt, Chinook salmon, steelhead, threespine stickleback, prickly sculpin, Pacific staghorn sculpin, Sacramento perch, tule perch, starry flounder	Tidal sloughs likely supported various combinations of species present in Suisun Bay and the Delta depending on local and regional environmental conditions, particularly freshwater discharge through the Delta and resulting water salinities, and slough location, configuration, accessibility, and size. Sloughs functioned as migration corridors for adult Pacific lamprey and steelhead to upland streams, and juvenile steelhead and Chinook salmon used tidal sloughs in conjunction with tidal marsh for rearing.
Tidal marsh	Tidal marsh bordering Suisun Bay and the Sacramento-San Joaquin Delta	Thicktail chub, hitch, Sacramento splittail, Sacramento pikeminnow, Sacramento sucker, Chinook salmon, steelhead, threespine stickleback, prickly sculpin, Pacific staghorn sculpin, Sacramento perch, tule perch	Tidal marshes supported similar but less diverse assemblages of native fishes compared to tidal channels, in part, because dense marsh vegetation restricted access and movement by large-bodied fish species and individuals. Juvenile steelhead and Chinook salmon used tidal marsh in conjunction with tidal sloughs for rearing.
Panne	Pannes embedded within tidal marsh bordering Suisun Bay and the Sacramento-San Joaquin Delta	Sacramento splittail, threespine stickleback	Pannes typically were embedded within dense tidal marsh vegetation, which restricted access by most fishes. Pannes were characterized by intermittent, seasonal ponding. Waters were often shallow, warm, and exhibited high salinities relative to tidal channels, depending largely on freshwater outflows in the Delta and local environmental conditions.
STREAM AND RELATED FEATURES			
Large perennial stream	Low- to mid-elevation Brushy Creek Mid- to upper-elevation Marsh Creek Mid-elevation Kirker Creek Mid- to upper-elevation Mount Diablo Creek	Pacific lamprey, hitch, California roach, Sacramento pikeminnow, Sacramento sucker, steelhead (Marsh and Mount Diablo creeks only - potential migration corridor and spawning and rearing habitat adults and juveniles), threespine stickleback, tule perch, prickly sculpin	Perennial streams were uncommon in the study area and were typically associated with areas of groundwater discharge from seeps and springs along reaches underlain by impervious formations such as bedrock. Higher fish species diversity likely would be found in the mid-elevation reaches of larger streams characterized by deep, permanent pools, compared to small, upper-elevation reaches.
Small perennial stream	Mitchell Creek	Pacific lamprey, California roach, Sacramento sucker, steelhead, threespine stickleback, prickly sculpin	Perennial tributary streams typically were small and located in the headwaters of watersheds. Pools would vary from small to moderate in size and depth, and would be characterized by cool summer water temperatures and coarse sand-gravel-cobble-boulder substrates. Perennial tributaries would serve as spawning and rearing habitat for steelhead and/or resident rainbow trout.
Large lower-intermittent stream	Marsh Creek	Pacific lamprey, thicktail chub, hitch, California roach, Sacramento blackfish, hardhead, Sacramento pikeminnow, Sacramento sucker, steelhead, threespine stickleback, prickly sculpin, Sacramento perch, tule perch	Evidence suggests that lower Marsh Creek dried each year and few, if any, pools persisted through late summer. Fish species would use the intermittent reach seasonally, and as a migration corridor to suitable upstream perennial and intermittent habitats. Fish trapped as the stream dried would perish.
Mid- to upper-intermittent	Marsh Creek	Pacific lamprey, thicktail chub, hitch, California roach, hardhead, Sacramento pikeminnow, Sacramento sucker, steelhead, threespine stickleback, prickly sculpin, tule perch	Fish assemblage likely highly variable depending on local environmental conditions. Small intermittent channels would be less diverse than larger intermittent streams with deep, permanent pools. Reaches would function as a migration corridor for adult steelhead to upstream perennial reaches and smolts emigrating downstream.
Small intermittent stream	Many small creeks descending from foothills (e.g., Willow, Kirker, Markley Canyon, West and East Antioch, Frisk creeks) or creeks seasonally connected with larger tributaries or mainstem streams (e.g., Sand, Deer, Kellogg creeks), often only seasonally connected with tidal or perennial wetland or stream habitats.	May be fishless or support hitch, California roach, Sacramento sucker, and threespine stickleback.	Assemblage likely highly variable depending on local environmental conditions. The smallest and driest intermittent streams may have been fishless in most years. Small intermittent channels would support fewer fish species than larger intermittent streams with deep permanent pools.
Small discontinuous streams and distributaries	Many small creeks descending from foothills on to alluvial fans. See many unnamed creeks in northwest portion of study area.	Typically fishless unless there is a seasonal surface hydrologic connection with wetland or other large stream habitats.	Small streams and channels typically ephemeral or intermittent with little or no suitable habitat for fishes.
Springs	Geographically widespread throughout the study area. For example, Byron Hot Springs in the Brushy Creek watershed was a large group of springs.	Typically fishless. Possibly California roach and/or threespine stickleback.	Fish could colonize perennial springs if there were periodic, seasonal surface hydrologic connections with wetland or other stream habitats.
PALUSTRINE WETLAND			
Wet meadow	Occurred primarily within the northwest portion of the study area often adjoining tidal marshes.	Typically fishless. Possibly hitch, Sacramento splittail, California roach, and/or threespine stickleback.	During periods of moderate- to high- seasonal precipitation and flooding it is possible fish would enter wet meadows from adjoining tidal marsh or stream habitats. Fish would move back to permanent wetlands and waters as the wet meadows dried, or they would be trapped and perish.
Seeps	Geographically widespread throughout the study area.	Fishless	Seeps were characterized by shallow subsurface to surface water saturation. Seeps were likely critical in supporting native fishes through the discharge of cool groundwater into summer pools embedded within otherwise summer dry stream reaches.
Perennial valley freshwater marsh	Upper Brushy Creek watershed	Typically fishless or possibly California roach, hitch, threespine stickleback, Sacramento perch, and tule perch.	Colonization would be possible Where surface hydrologic connections between freshwater marshes and other perennial wetlands (i.e., alkali marsh) and stream habitats were present.

Table 4.1., continued

Habitats	Example(s) (with relevant illustrations)	Probable Native Fish Assemblage[1]	Notes on Habitat Use
PALUSTRINE WETLAND, continued			
Seasonal lake; seasonal pond	Headwaters of Briones Creek watershed	Typically fishless unless associated with floodplains. Possibly hitch, Sacramento splittail, California roach, and/or threespine stickleback.	Seasonal ponds were typically found embedded in upland landscapes such as grassland. However, during flooding if ponds formed on floodplains adjacent to tidal waters, then fishes could be present seasonally.
Permanent pond	Headwaters of Lawlor Ravine and Frisk Creek and in wet meadows near the tidal marsh	Typically fishless unless associated with floodplains. Possibly hitch, Sacramento splittail, California roach, Sacramento sucker, threespine stickleback, tule perch, and/or Sacramento perch.	Permanent ponds were typically found within freshwater marshes or seasonally flooded wet meadow, although one occurred within grassland. Permanent ponds formed on floodplains adjacent to tidal waters and streams could support fishes.
ALKALI WETLAND			
Alkali perennial pond	Upper Frisk Creek watershed	Typically fishless or possibly threespine stickleback, hitch and California roach.	Colonization by alkali tolerant fishes would be possible where surface hydrologic connection to other perennial wetlands (*i.e.*, alkali marsh) and stream habitats were present.
Alkali marsh	Brushy Creek, Upper Frisk Creek	Typically fishless or possibly threespine stickleback, hitch, and California roach.	Colonization would be possible by alkali tolerant fishes where surface hydrologic connections with other stream habitats were present.
Alkali flat	Brushy Creek	Typically fishless or possibly threespine stickleback, hitch and California roach.	Colonization by alkali tolerant fishes would be possible where surface hydrologic connections with other perennial wetlands (*i.e.*, alkali marsh) and other stream habitats were present.
Alkali meadow/ sink scrub	Mid- to lowermost Brushy and Frisk creeks	Typically fishless or possibly threespine stickleback, hitch and California roach.	Seasonal flooding in some years may have formed a continuous but intermittent surface hydrologic connection between alkali flat, alkali marsh, valley sink scrub, tidal marsh, and stream habitats allowing for the movement of fishes between habitats.

[1]The probable fish assemblage was derived from historical and recent records and accounts of fish occurrences assessed 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, annual precipitation patterns, and Sierra snowfall levels and spring and summer runoff characteristics within the Delta, among other environmental factors. For example, fish species diversity and population abundance and persistence would varying temporally along several environmental axes, most notably the amount and distribution of annual precipitation, water temperature, and the availability of food and cover.

Figure 4.30. Two isolated pools along an otherwise dry reach of Middle Marsh Creek in 2011. Permanent isolated pools function as refuges for native fishes and other vertebrates during late summer and fall. These pools contained native fishes such as California roach (*Lavinia symmetricus*), threespine stickleback (*Gasterosteus aculeatus*), and Sacramento sucker (*Catostomus occidentalis*). The pool in the top image also contained Pacific pond turtle (*Actinemys marmorata*) and California red-legged frog (*Rana draytonii*). (Photos by Robert Leidy)

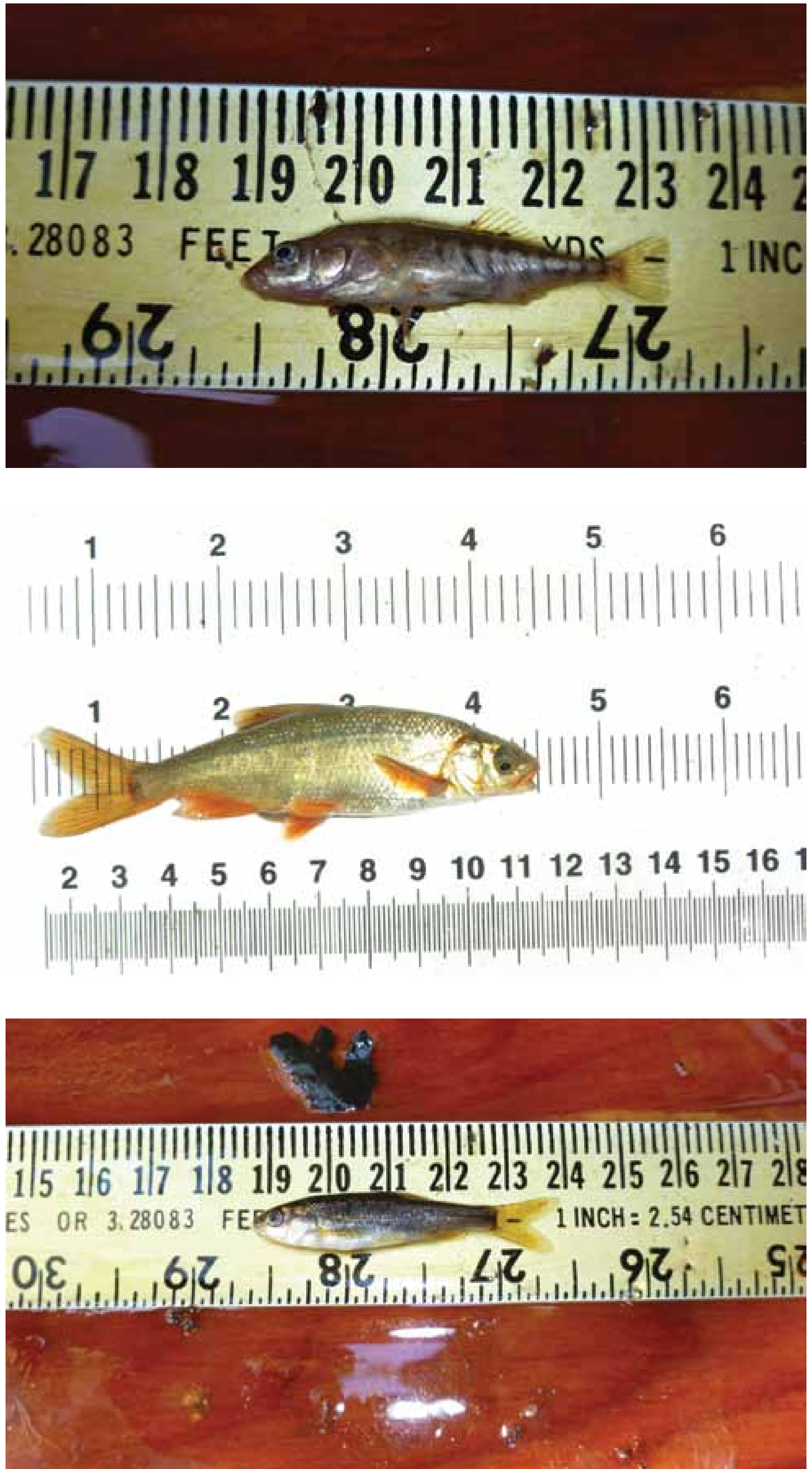


Table 4.2. Historical status and evidence for native fish assemblages in East Contra Costa County.

FAMILY/ SPECIES	ZOO-GEOGRAPHIC TYPE	LIFE HISTORY STATUS	DISTRI-BUTIONAL STATUS	PRIMARY HABITAT OCCURRENCE	NOTABLE EARLY RECORD(S) FROM THE WATERSHED(YEAR) (SOURCE)
ACCIPENSERIDAE/ STURGEONS *Acipenser* sp. white or green sturgeon	OBF-SD	M, AND, EST	W/U (restricted to tidal channels)	TER, L/OB	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004)
CYPRINIDAE/ MINNOWS ***Gila crassicauda*** **thicktail chub**	OBF-FD	FWR	LC, P (now extinct)	MR, FS, PFP	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004)
Lavinia exilicauda **hitch**	OBF-SD	FWR	LC, W	MR, FS, PFP	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004 Marsh Creek, 7.5 mi. east of Mount Diablo (1939)(UMMZ 133178) Marsh Creek, 0.5 mi. east of Marsh Creek Springs Park (1945)(CAS 17931) Kellogg Creek (1995)(CAS 87771, 87772) Brushy Creek, between ponds 2 and 3 (1997)(EBRPD 1997)
Lavinia symmetricus **California roach**	OBF-FD	FWR	LC, W	MR, TC, SC	Marsh Creek, 0.15 km east of BM 485, Marsh Creek Rd. (1981)(Leidy 2007) Marsh Creek, 1 mi. above Dunn Creek confluence (1995)(Slotton *et al.* 1996) Brushy Creek, between ponds 2 and 3 (1997)(EBRPD 1997)
Orthodon microlepidotus **Sacramento blackfish**	OBF-FD	FWR	LC, W	MR, FS, PFP	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004)
Pogonichthys macrolepidotus **Sacramento splittail**	OBF-FD	FWR, EST	LC, W (restricted largely to tidal channels)	TER, LLR	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992)
Mylopharodon conocephalus **hardhead**	OBF-FD	FWR	U, P	LMR	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992)
Ptychocheilus grandis **Sacramento pikeminnow**	OBF-FD	FWR	LC, W	MR, FS	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004) Marsh Creek, at Cypress Road crossing (1981)(Leidy 2007)

Figure 4.31. Native fishes from Mount Diablo Creek and Marsh Creek. (top) Threespine stickleback (*Gasterosteus aculeatus*) and (bottom) California roach (*Lavinia symmetricus*) from upper Mt. Diablo Creek, taken in 2011. Middle photo shows a hitch (*Lavinia exilicauda*) from lower Marsh Creek in 2010. (Photos by Robert Leidy)

Table 4.2., continued

FAMILY/ SPECIES	ZOO-GEOGRAPHIC TYPE	LIFE HISTORY STATUS	DISTRI-BUTIONAL STATUS	PRIMARY HABITAT OCCURRENCE	NOTABLE EARLY RECORD(S) FROM THE WATERSHED(YEAR) (SOURCE)
CATOSTIMIDAE/ SUCKERS ***Catostomus occidentalis*** **Sacramento sucker**	OBF-FD	FWR	LC, W	MR, FS, TC, SC, PFP	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004) "Six miles back of Clayton" (1927)(SU 60178) Marsh Creek, 3 miles east of Livermore (1939)(FLMNH 7860) Marsh Creek, 0.5 mi. east of Marsh Creek Springs Park (1945)(CAS 17933) Marsh Creek, at Cypress Road crossing (1981)(Leidy 2007)
SALMONIDAE/ SALMON & TROUT *Oncorhynchus mykiss* rainbow trout/steelhead	OBF-SD	M, AND, FWR	U	MR, TC	"Back of Martinez, toward the foot of Monte Diablo", as *Salmo rivularis*, 16 April 1855 (Ayres 1855)(possibly Mount Diablo Creek watershed). Mitchell Canyon Creek, April 1985 (Leidy, Becker and Harvey 2005).
Oncorhynchus tshawytscha Chinook salmon	OBF-SD	M, AND, FWR	U, P	LLR, LMR, L/OB	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) Marsh Creek, Delta Road near Oakley (1995)(Slotton *et al.* 1996) Marsh Creek, various locations below drop structure (2001-2007)(Puckett pers. comm.)
GASTEROSTEIDAE/ STICKLEBACKS *Gasterosteus aculeatus* threespine stickleback	OBF-SD	M, EST, AND, FW	LC, W	MR, FS, TC, PFP	Kellogg Creek near Byron (1937)(CAS 212818) Marsh Creek, 0.15 km east of BM 485, Marsh Creek Rd. (1981)(Leidy 2007)
COTTIDAE/ SCULPINS *Cottus asper* prickly sculpin	OBF-SD	AMP, EST, FWR	LC, W	MR, FS, TC, SC, PFP	Marsh Creek, bridge 4 mi. east of Byron (1942)(CDFG) Marsh Creek at Delta Road and Big Break (2008)(Slotton and Ayres 2009)
CENTRARCHIDAE/ SUNFISH ***Archoplites interruptus*** **Sacramento perch**	OBF-FD	FWR	LC, W (now extirpated)	MR, FS, PFP	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-18, 1000-1500 A.D. (Gobalet 1992) CCO-548, 755-550 B.C. (Gobalet 2004)
EMBIOTOCIDAE/ SURFPERCH ***Hysterocarpus traskii*** **tule perch**	OBF-SD/FD	FWR	LC, W	MR, FS, PFP	Lower Marsh Creek at John Marsh State Historic Park, archeological sites CCO-548, 755-550 B.C. (Gobalet 2004)

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.

Likely historical distributional status in study area streams: LC = locally common; W= geographically widespread; U = uncommon/rare; P = historical 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.

Sources: CAS = California Academy of Sciences, San Francisco; CDFG (California Department of Fish and Game); EBRPD (East Bay Regional Park District); FLMNH = Florida Museum of Natural History; SU = Stanford University fish collection (housed at CAS, San Francisco); UMMZ = University of Michigan Museum of Zoology.

SUMMARY OF FINDINGS

1. **Most ECCC streams maintained single thread channels.** With one exception, no multi-channel or braided reaches were documented in ECCC; streams tended to be meandering and to occupy a single channel. The exception was lower Marsh Creek, which had a seven-mile side channel. This channel was likely a remnant former channel, which carried water during high flows and provided valuable side channel habitat for native fish.
2. **Historically, most ECCC streams were discontinuous.** Few streams maintained a defined channel along their entire length. Most ECCC streams drained to seasonal wetlands which emptied into the tidal marsh. This diffuse drainage system contributed to the formation of seasonal wetlands and slowed the movement of flood waters through the system.
3. **The present day stream network is much more highly connected than the historical system.** Artificial channels have replaced discontinuous swales and seasonal wetlands, helping to speed the passage of water through the system, and likely increasing downstream challenges such as flooding or bank erosion.
4. **The large seasonal and inter-annual variation in precipitation resulted in variable hydrologic connectivity and flow.** In wet years, streams would have formed broad combined overflow areas and retained surface flow further into the dry season. The distribution of native fish and other fauna presumably followed these stream patterns.
5. **Historically, most ECCC streams were intermittent.** Most streams carried flow for only part of the year, drying through the summer.
6. **Relatively few perennial reaches and pools existed historically,** and these were mostly in the upper reaches of watersheds, and in the SE corner of the study area. Many were associated with springs. These small perennial water sources likely provided important habitat in a largely dry region. Some of these pools persist today.
7. **Approximately 75% of the contemporary channel network follows the historical alignment.** The remaining 25% of the contemporary network follows a new course that differs from the historical alignment by at least 50 feet. Modifications to the historical network include channel extensions to increase connectivity, changes in alignment, and straightening of meanders. Overall, the historical stream network contained 477 miles of channel, compared to 438 today.
8. **Most of the extension and straightening of the channel network has occurred in the lower reaches.** The upper watersheds were more constrained by topography and less impacted by early agriculture, while the lower watersheds were prone to overflow and often had more diffuse, less well defined channels. As a result, most modifications have focused on the lower reaches of streams. Over 57% of lower reaches (plains unit) follow a new or modified course.
9. **In contrast to many Bay Area streams, the watersheds of ECCC had relatively sparse, oak dominated riparian corridors.** ECCC streams developed herbaceous and sparse tree cover in response to the high temperatures and low rainfall. This dry-adapted riparian cover may provide a useful model for a region considering the challenges of climate change.
10. **Riparian tree density has increased since 1939.** In 1939, more dense riparian cover historically existed in the upper watersheds, while the plains were dominated by herbaceous riparian cover. There has been an overall shift to greater density through the region. For example, along Marsh Creek there was a shift from open and sparse canopy cover to closed canopy cover.
11. **While broad riparian reaches and willow swamps were found in many Bay Area watersheds** (e.g., Napa River, Alameda Creek, Guadalupe River, Stevens Creek, Sausal Creek), we found no evidence of these features in ECCC. This is presumably due to topography and/or climatic effects.

MANAGEMENT IMPLICATIONS AND NEXT STEPS

1. **Modifications to the watershed have caused it to transport water more rapidly downstream**. Increased channel connectivity and decreased storage enables water to drain rapidly to the Bay-Delta rather than collecting in seasonal wetlands and recharging groundwater aquifers. This likely results in higher peak flows. (In some cases, however, constructed reservoirs and stock ponds have the opposite effect, retaining some water for much longer periods.) Strategic LID (low impact development), water retention, and local groundwater recharge can help reverse some of these effects.
2. **Further research could be conducted to establish if and how flow patterns today differ from historical flow patterns.** Limited historical sources indicate that some reaches may have been wetter historically. In contrast some may have increased dry season flow due to reservoir releases and urban runoff. Research to establish the locations of perennial reaches today and evaluate changes to flow patterns will help managers identify appropriate dry season flow targets.
3. **Riparian restoration efforts should consider the diversity of riparian habitat types present historically,** as well as present-day hydrology. Riparian vegetation varied from herbaceous cover to dense riparian forest to scattered oaks, and many streams historically had relatively sparse tree cover compared to other Bay Area systems. A one size fits all approach may not result in viable riparian vegetation.
4. **ECCC provides a useful conceptual model for riparian restoration in relatively dry climates.** ECCC streams were adapted to low rainfall, semi-arid conditions, while providing important ecological functions.
5. **Future research could help establish whether 1939 was representative of historical riparian conditions,** or was a low point in tree cover. The increased density since 1939 could represent recovery to historical conditions, or it could represent a shift to higher densities due to increased flows (urban runoff, dams and stock ponds) or planting. Research into the cause of this shift would help managers determine appropriate, sustainable riparian cover targets.

Figure 4.32. Tributary to Brushy Creek. This channelized tributary to Brushy Creek was the subject of a recent restoration effort. Historical ecology findings about the site helped design a project that utlizes renmant wetland features. (Photo by East Bay Regional Park District)

CHAPTER 5
WETLAND HABITATS

It is Tule land, the whole of it and formerly the tules grew very high – below the roots of the Tule and grass the land is very soft and mucky – many places pools and ponds of water stand during the year, produced by the tides.

— WILLIAM SMITH 1865, DESCRIBING NORTHERN END OF LOS MEDANOS LAND GRANT

WETLAND HABITATS

Wetlands provide a host of functions, including fine sediment and floodwater storage and habitat for protected species. In a semi-arid region such as East Contra Costa County (ECCC), wetlands tend to be relatively uncommon and therefore those that do exist are even more ecologically significant. Species associated with wetlands in ECCC include California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), and San Joaquin spearscale (*Atriplex joaquiniana*) (Jones & Stokes 2006). Greater understanding of the natural distribution and physical settings of local wetlands can increase the likelihood of sustainable restoration strategies (Montgomery 2008).

The type of wetlands available in ECCC has shifted. Historically, wetlands ranged from seasonally flooded alkali flats to ponds to small freshwater marshes to vast seasonally flooded wet meadows (fig. 5.1). Excluding tidal marshlands, historical wetlands covered 13,000 acres, 2.5 times as much area as they do today, and tidal marshlands covered an additional 22,000 acres. Most nontidal wetlands were historically seasonal and alkali-influenced, and clustered towards the eastern and northern edges of the study area. Today the wetlands of ECCC are largely man-made, including over 100 acres of stock ponds and over 2,000 acres of constructed reservoirs and aqueducts. Much of what has been lost is the extent of seasonal wetlands, causing a shift in wetland type towards permanent, open water wetlands.

The HCP requires restoration of a variety of wetland types (Jones & Stokes 2006). Different types of wetlands support different types of species: alkali wetland and vernal pool habitats in ECCC are associated with species such as Vernal pool fairy shrimp (*Branchinecta lynchi*) and Adobe navarretia (*Navarretia nigelliformis* ssp. *nigelliformis*) (Jones & Stokes 2006), while freshwater habitats are associated with Western pond turtle (*Clemmys marmorata*), Giant garter snake (*Thamnopsis gigas*), and Tricolored blackbird (*Agelaius tricolor*; Jones & Stokes 2006).

To address questions of historical extent and distribution, we documented the distribution of wetland habitat types prior to significant Euro-American

Figure 5.1. Wetland habitats and associated species. A vernal pool at Vasco Caves (A) provides habitat for special status species, including vernal pool fairy shrimp *(Brachinecta lynchi;* B). A freshwater pond near Brushy Creek (C) supports a juvenile red-legged frog *(Rana aurora draytonii;* D). (E) This image is labeled "From Frank Cabrall's sheep camp looking N. on lake located on N line of SW 1/4 Sec 19 - IS-3E" which is apparently located near Frisk Creek, possibly at the site of a historical perennial alkali pond. (A-D: photos by Abigail Fateman, Contra Costa County; E: Unknown ca. 1920, courtesy of the California Historical Society)

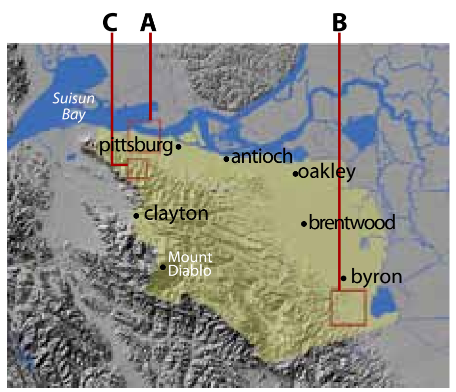


Figure 5.2. Three major wetland habitat types. (A) Tidal marsh occurred in both the northern and eastern portions of the study area. Shown here are historical marsh, sloughs, and tidal ponds just east of present-day Pittsburg. (B) The eastern plains supported a mosaic of alkali wetlands, as shown in this area surrounding Byron Hot Springs. (C) This creek flowed north into a valley freshwater marsh and a perennial pond in upper Lawlor Ravine (near present-day Keller Canyon Landfill); further north, the creek passed through a wet meadow.

modification based on available historical evidence. We found three major classes of wetland types within ECCC: tidal marshes at the lowland margins of the study area; alkali-associated wetlands in the eastern plains and foothill valleys; and an array of freshwater non-tidal (palustrine) wetlands, such as valley freshwater marshes, wet meadows, ponds and pools, and springs (fig. 5.2, 5.3). In this chapter, we first describe our methods for each of the three habitat types, then present our results, and finally discuss potential conservation implications.

METHODS

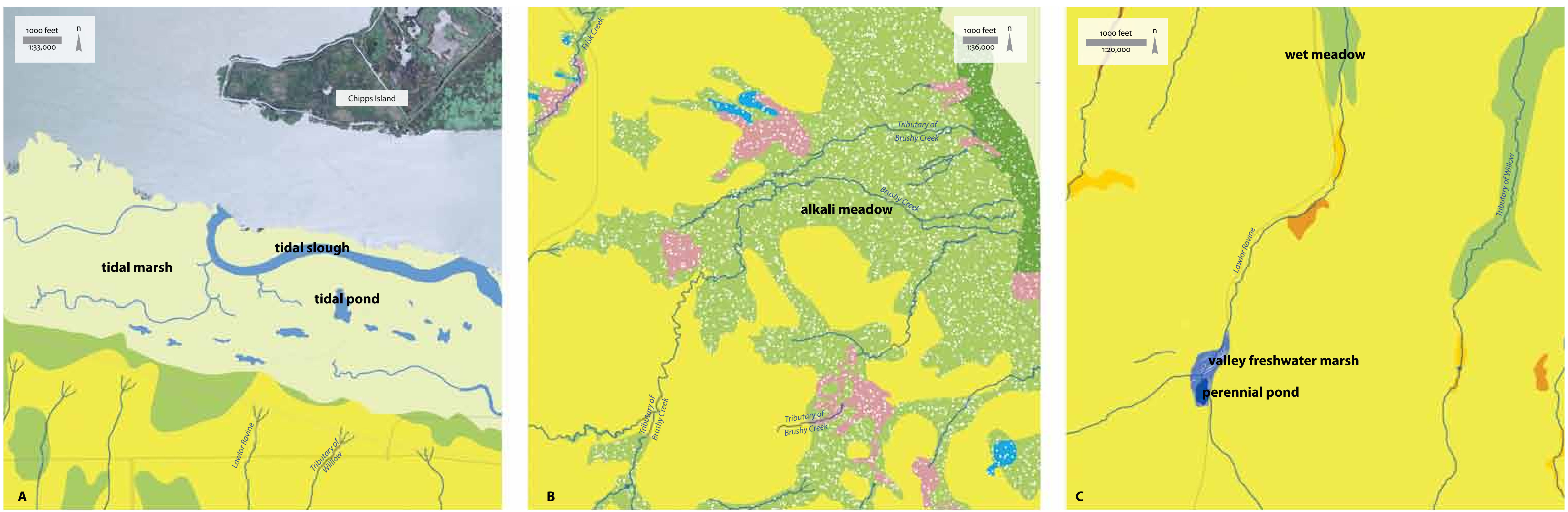
Tidal Marsh

Tidal marshes are intertidal wetlands that support at least 10% cover of vascular vegetation adapted to intertidal condition. Marsh plains, tidal ponds, and channel networks are characteristic features or habitat elements of tidal marsh (Collins and Grossinger 2004).

Our process for mapping tidal marsh differed in the east and west regions of ECCC. Between Clyde and Antioch, we combined large-scale 1880s U.S. Coast and Geodetic Survey (USCS) topographic sheets (T-sheets) with a less-detailed but earlier 1866 T-sheet. Where the two sets of maps generally agreed, we mapped from the 1880s T-sheets because of their higher spatial resolution. We used details from the 1866 T-sheet in cases where the 1880s maps showed signs of recent modification.

The T-sheets did not extend east beyond Antioch, so to map the remainder of the study area we brought in additional sources. We based our mapping on work by Brian Atwater (1982) and modified his historical boundary with sources such as nineteenth-century General Land Office (GLO) Public Land Survey notes, U.S. Geological Survey (USGS) quadrangles and other historical maps, information from the 1933 soil survey and accompanying 1939 report, and the 1939 aerials (see further discussion in appendix). Tidal channels in this eastern marsh were mapped as part of the Sacramento-San Joaquin Delta Historical Ecology study (Whipple et al. forthcoming, www.sfei.org/DeltaHEStudy).

Most tidal marsh falls outside of the HCP boundary, so we used two additional sources of contemporary mapping to compare historical to modern extent. For the northern shore west of Antioch, we used the contemporary shoreline mapping from the Bay Area EcoAtlas (SFEI 1998). For the eastern tidal marsh, we used the contemporary land cover mapping produced by the California Department of Water Resources Land and Water Use Office (Hawkins 2007). This data did not include tidal marsh as a cover type, so we assumed contemporary tidal marsh cover was a subset of the "native vegetation" category where it fell within our mapped historical tidal marsh.



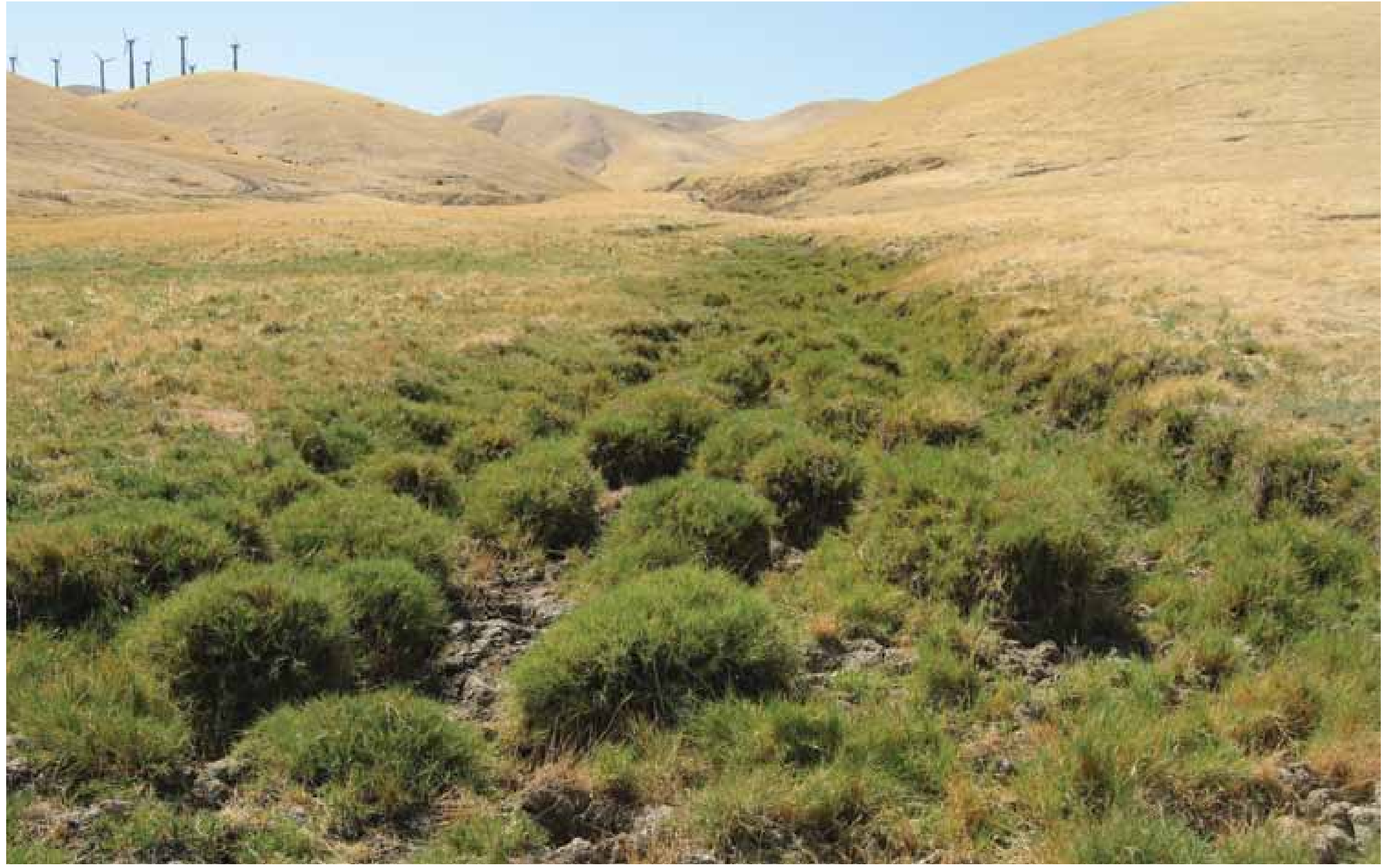


Figure 5.3. Hummocky saltgrass. This alkaline meadow habitat occurs today along a tributary to Frisk Creek in southeastern Contra Costa. (Photo by Abigail Fateman, CCC)

Alkali Habitats

Alkali-associated habitats typically occur in mosaics of salt-influenced seasonal and perennial wetland types (Holland 1986, Jones & Stokes 1989). The distribution of individual alkali habitat types corresponds to soil saturation and groundwater depth, ranging from seasonally inundated alkali meadow to perennially wet alkali marsh (Jones & Stokes 1989, Elmore et al. 2003). Alkali habitats tend to occur on slow draining clay soils in flat areas that allow water to pool and evaporate, concentrating alkali salts towards the surface.

To define the historical extent of alkali-associated habitats, we used a two-step process. First we produced a map of historical alkali extent by refining the contemporary HCP alkali mapping with historical and contemporary soils maps, aerial imagery, and the contemporary slope raster (see additional discussion in appendix). The 1933 soil survey mapped areas with alkali concentrations above 0.2%, which helped us to establish the presence of a band of alkali as a transition zone between the upland oak savanna and the tidal marsh (see fig. 5.4). Once we had established an alkali boundary, we divided the area into four different alkali-associated habitat classes: alkali meadow, alkali sink scrub, alkali flat, and alkali marsh.

WHY DO ALKALI WETLANDS OCCUR?

Salt naturally occurring in soils can originate from a number of sources. Areas close to the ocean and tidal influence can receive salts from salt water overflow and sea spray. Inland areas receive salts from the weathering of parent material. These inland areas can become alkaline when they occur with clay soil types, flat topography, an arid or semi-arid climate in which evaporation exceeds precipitation, and a high water table (Brady and Weil 2002). On clay soils where the groundwater level is close to the surface, salts are drawn upward by capillary action, resulting in high concentrations of salts very near the surface. Rainfall and runoff pond on the surface, unable to penetrate the fine-grained clay soils. As the trapped water evaporates, it forms a crust of sodium and other minerals on the surface (Biggar et al. 1984; fig. 5.4).

Alkalinity can also result or increase from human activities. Irrigation of crops can raise the water table and introduce additional salts (Hilgard 1892). In the western San Joaquin Valley, an estimated 1.9 million metric tons of salts are added to the soils daily through the application of irrigation water (Letay 2000). Salt levels are raised through a combination of trapped marine sediments in the soil working towards the surface and direct application of low levels of salt to the land in irrigation water (Biggar et al. 1984).

Early U.S. Department of Agriculture soil surveys were developed to describe the agricultural potential of each soil type. The soil scientists delineated areas of alkaline soils in part because the alkalinity interfered with the growth of crop plants. The variation of soluble salt levels in the soil was measured and mapped carefully to identify areas that could be reclaimed (i.e., successfully farmed after treatment) and those that were too salty or alkaline to support viable crops (USDA 1951). Reports on the presence of alkaline soils were sometimes met with opposition from land developers who feared that the publication of this information would result in lower land values (Durana and Helms 2002).

Levels of alkalinity in an area can decline for a number of reasons, including treatment of soil with gypsum or other neutralizing agents to improve agriculture (Jones & Stokes 2006), changes in the fire regime, drainage, livestock grazing, the use of some crop types, and urbanization (Gregor 1953, Elmore et al. 2006).

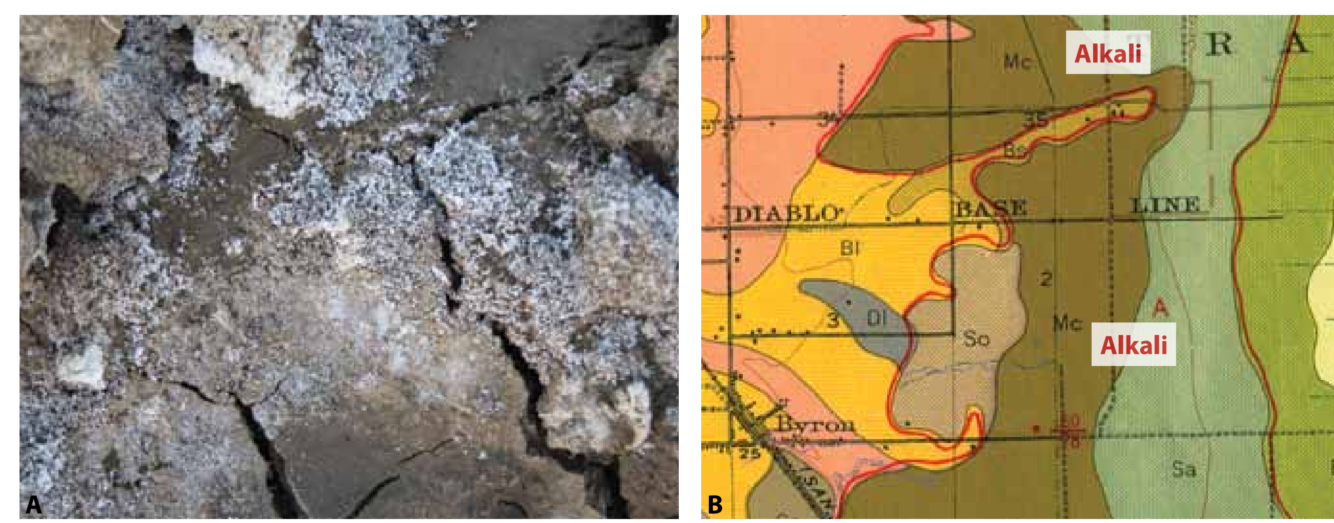


Figure 5.4. Alkali indications. (A) A crust of salt and other minerals is left on the cracked ground after pooled water evaporates near Byron. (B) The 1933 USDA soil map delineates alkali areas using a red line - areas in the center of the image between the two red lines were measured with alkali levels above 0.2% in the first six feet. A measurement of soil salinity taken in the field of both the surface and of the average in a six-foot section is shown on the map in red within the alkali area. (A: photo by Abigail Fateman, CCC; B: Carpenter and Cosby 1933)

Alkali Meadow

Alkali meadows 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 and/or vernal pools/swales (Baye et al. 2000, Holstein 2000). These habitats typically have high groundwater levels and are subject to temporary to seasonal flooding, with subsequent drying through the summer (Holland 1986, Elmore et al. 2006). Dominant plant species include saltgrass (*Distichlis spicata*), wild barley (*Hordeum* spp.), saltbush (*Atriplex* spp.), alkali heath (*Frankenia salina*), and alkali weed (*Cresta truxillensis*) (Jones & Stokes 2006).

Historical alkali meadow extent was defined by the extent of mapped alkali wetland areas (see process above) that were not identified by other information as alkali marsh, flat, or sink scrub. However, the alkali meadows inevitably contained smaller, unidentified patches of these other types.

Alkali Sink Scrub

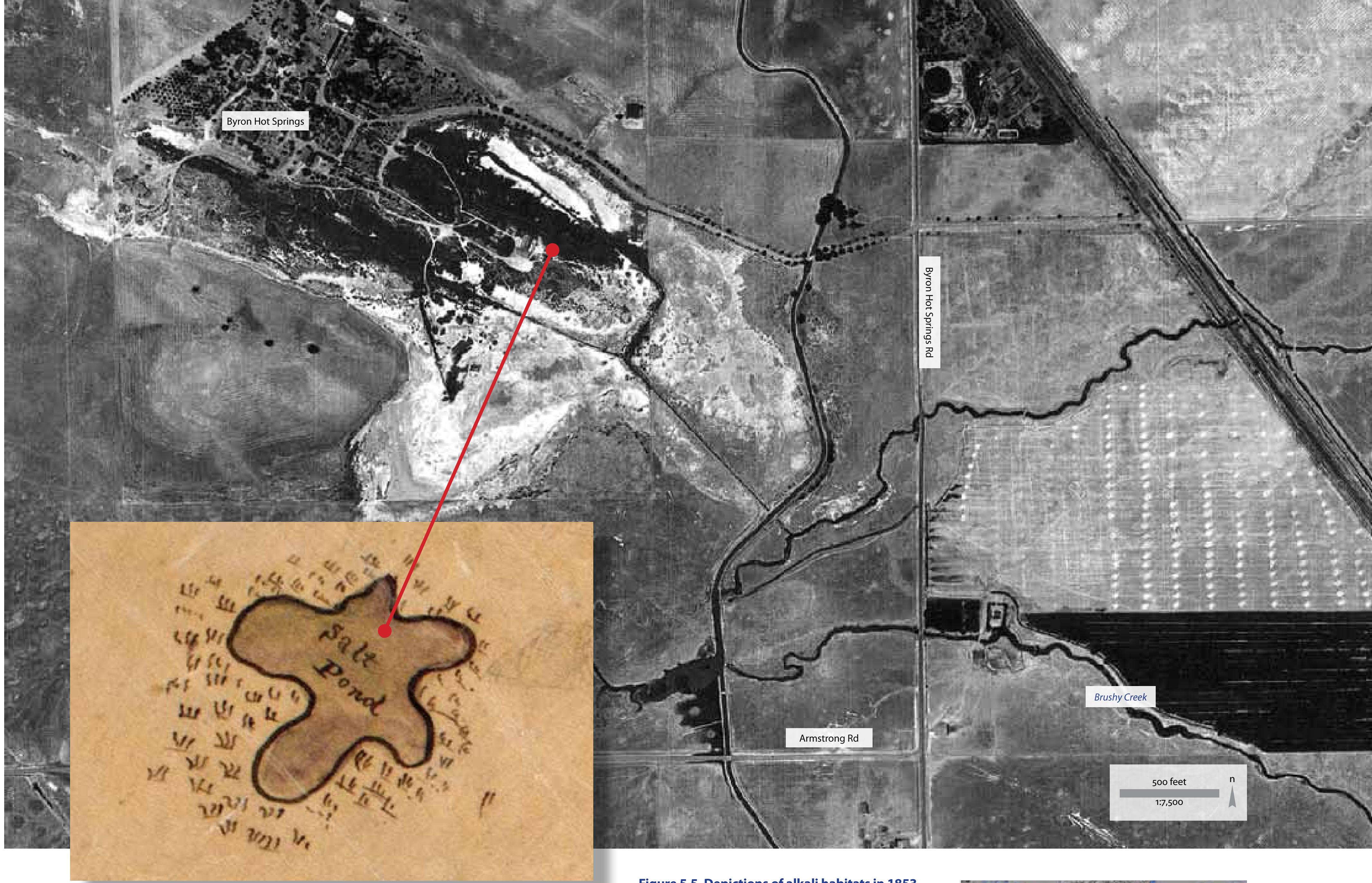
Alkali sink scrub (also known as valley sink scrub) describes seasonal wetlands with salt-tolerant vegetation and a clay substrate dominated by scrub cover (Holland 1986, Coats et al. 1988, Jones & Stokes 1989). Typical scrub species include iodine bush *(Allenrolfea occidentalis)*, seep weed *(Suaeda spp.)*, and other members of the alkali tolerant Chenopodiaceae family (Holland 1986).

We identified patches of alkali sink scrub by a distinctive stippled signature on the historical aerial photographs. Additional evidence came from an 1853 map of the region, which identified a large feature in the same area as "matteral," symbolized in the same way that scrub is elsewhere on the map (Whitcher 1853a). The term is likely a reference to the shrubby cover – *matoral* or *matorral* are translated from Spanish as "thicket, underbrush" (Williams 1962) and "shrubland, weeds" (Minnich 2008). The label and mapped shape suggest that the cover type in this region differed from the surrounding areas and was dominated by shrubs. The shape and extent of this feature correspond to the visible scrub patterns in 1939 aerial imagery, despite the intervening time (fig. 5.5)

By 1939, when the historical aerials were produced, much of the sink scrub cover had been replaced by crops and developments. Traces of alkali sink scrub show through some fields in the aerial, and we used these indications to extend sink scrub cover through areas where its absence was obviously due to human development. The resulting approximation of 2,000 acres is still a conservative estimate of the historical extent of alkali sink scrub.

Alkali Flats

Alkali flats or playas are intermittently flooded lakes characterized by mostly unvegetated, alkali-affected clay substrate (Holland 1986). Alkali flats were mapped based upon their distinctive light-colored, barren signature in early aerial photography, which corresponded closely to known contemporary remnants (and historical remnants; see fig. 5.5). Several large features were also supported by 19th century maps and GLO field notes.



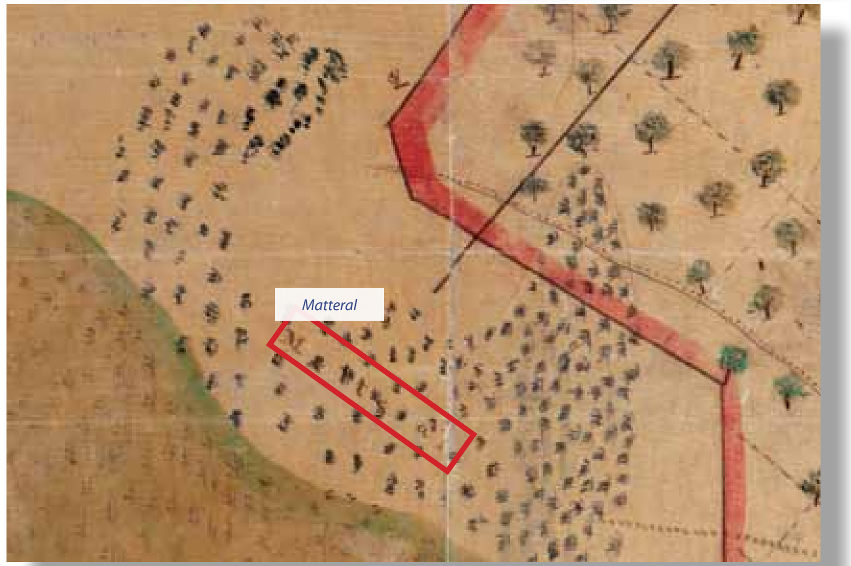


Figure 5.5. Depictions of alkali habitats in 1853. In the 1939 aerial mosaic (above) the white scald created by an alkali flat at Byron Hot Springs is clearly visible, despite the construction of the Byron Hot Springs resort facilities over a portion of the area. This shape generally matches with the "salt pond" labeled in the 1853 land grant map at left, indicating that Byron Hot Springs has persisted over time as a seasonally flooded alkali flat. Another portion of this 1853 map provides evidence for alkali sink scrub. The word "Matteral" (shrubland, thicket), boxed in the image to the left, is attached to a symbol indicating scrub, which we found to match areas of alkali sink scrub. (USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; Whitcher 1853a, courtesy of The Bancroft Library, UC Berkeley)

Alkali Marsh

Alkali marshes are perennial wetland features, often fed by springs or seeps (Holland 1986). They support dense herbaceous vegetation, including species such as narrow-leaved cattail (*Typha angustifolia*), alkali bulrush (*Schoenoplectus maritiumus*), common monkey-flower, and yerba mansa (*Anemopsis californica*) (Jones & Stokes 1989).

Alkali marshes were identified as perennial wetland features within alkali soils. Some were documented directly from historical sources, while others were inferred from early aerial photography based on the appearance of heavily saturated soil (see fig. 5.13). Since the 1939 aerials were taken in the summer of a dry year after much modification had already taken place, our estimate of alkali marsh cover is almost certainly very conservative.

Palustrine Wetlands

We found evidence for a number of types of historical palustrine, nontidal wetlands in ECCC. These lands typically retain nearly all rainfall at or near the surface and receive additional surface runoff or seepage from adjacent uplands (see 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.

Wet Meadow

Wet meadows are seasonally flooded herbaceous communities characterized by poorly drained, clay-rich soils. Wet meadows are a type of seasonal wetland. They support a flora adapted to saturated conditions, as well as temporary ponds. Although these areas exhibited distinct, wetland-associated characteristics, and were consistently described by historical sources, in some cases the historical wet meadow classification may not signify that the entire area would have met contemporary jurisdictional wetland definitions.

Soil surveys provided our most detailed information for mapping wet meadows. These surveys carefully assessed the physical and drainage characteristics of each soil type to inform agricultural decisions. In a process similar to that followed for alkali areas, we evaluated the hydrogeomorphic characteristics of historical and modern soils to identify types exhibiting wet meadow/seasonal wetland characteristics (Grossinger et al. 2006, 2007). 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 a 1933 soil survey produced at twice this scale (1:62,500), we conservatively classify these boundaries within our medium level of certainty (500 ft/150 m).

In the 1977 soil survey, wet soils were labeled "poorly drained" or "very poorly drained" and were "subject to ponding" or had only limited vegetation growth due to high groundwater levels. In the 1939 soil survey report, wet soils were similarly described as "boggy," and had slow or poor drainage. We used the descriptive text accompanying the soil surveys to generate a list of historical and contemporary wet soils in East Contra Costa. Many of these soils had alkali influence, but six did not and were used in conjunction with topographic maps and aerial imagery to map wet meadow (table 5.1). We also classified some prominent depressions on Brentwood clay as wet meadow (Carpenter and Cosby 1933).

Perennial Freshwater Wetlands

Valley freshwater marshes are persistent emergent freshwater wetlands typically dominated by bulrushes (*Scirpus* spp.), cattails (*Typhus* spp.), sedges (*Carex* spp.), and rushes (*Juncus* spp.). These wetlands are seasonally flooded (Cowardin 1979); soils generally have a high organic content and are usually saturated (Holland 1986). Perennial ponds are permanently flooded, unvegetated areas, typically found within larger marsh complexes.

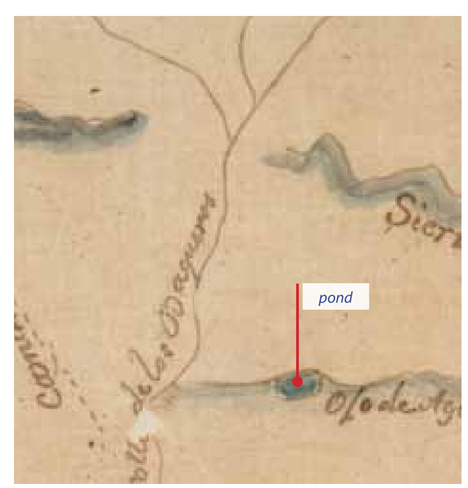
To identify perennial wetland features, including freshwater marshes, ponds, and springs, we relied on aerial imagery and early mapping. Aerial imagery from 1939 exhibited distinct wetland signatures in a number of places throughout the study area. As these images were taken during the summer of a dry year, any visible wet areas in these photographs are likely perennial wetlands. We were also able to map perennial wetlands directly from USGS, U.S. Coast Survey, and other maps based on standard cartographic symbols (fig. 5.6). Survey notes and textual evidence provided additional support.

We also mapped springs and seeps through the study area. Since we lacked a comprehensive historical source documenting the location of springs, we used the contemporary USGS mapping of springs, and added springs identified by historical sources. Springs present today are likely to have been present historically so we felt confident using the present day distribution for likely historical locations. However, some historical springs may have dried up – these are not captured in our habitat map.

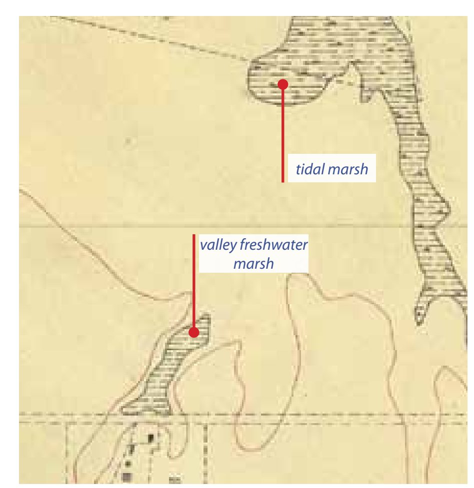
Table 5.1. Descriptions of soils used to identify wet meadows. We used six soils to identify historical wet meadows.

Soil type	Description	Source
Ambrose adobe clay	"the soil cracks badly to a depth ranging from 2 to 3 feet when dry," "absorbs moisture slowly"	Carpenter and Cosby 1939
Antioch loam	"so heavy and tight that roots penetrate it with difficulty," "in wet years subdrainage is impaired and the soil is boggy"	Carpenter and Cosby 1939
Olcott loam	"hard and baked when dry," "surface soil becomes boggy following heavy rains"	Carpenter and Cosby 1939
Clear lake clay	"poorly drained soils"	USDA 1977
Sycamore silty clay loam	"the water table is a limitation in places where the soil is not drained"	USDA 1977
Omni silty clay	"poorly drained," "subject to occasional ponding"	USDA 1977

Figure 5.6. Historical evidence for palustrine wetlands. These images show a variety of symbols used to indicate wetlands. From left to right: a pond near Kellogg Creek (A); tidal marsh and valley freshwater marsh near Antioch (B); a pond south of SR 4 near Bailey Road and the CNWS (C); and a dark area suggesting wet meadow near Pittsburg (D). (A: U.S. District Court, Northern District ca. 1840b, courtesy of The Bancroft Library, UC Berkeley; B: Davidson 1887, courtesy of NOAA; C: USGS 1896 (Mount Diablo); D: USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley)



A-ca.1840



B-1887

C-1896

D-1939

RESULTS

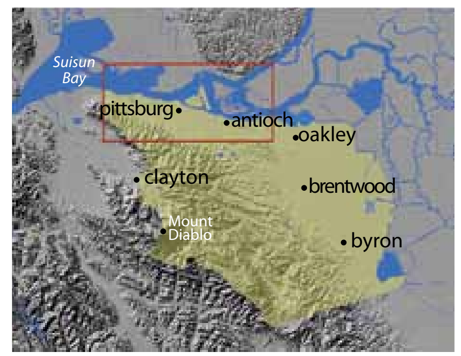
Regional Spatial Patterns

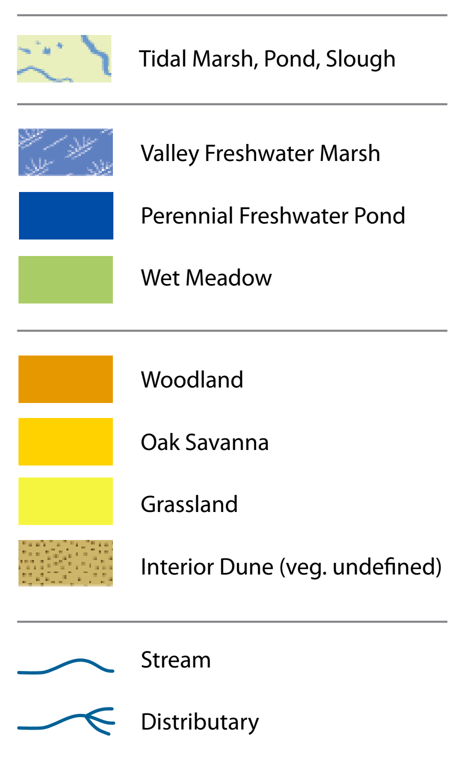
Before Euro-American modifications, ECCC supported a diverse array of seasonal and perennial wetlands (table 5.2). The tidal marsh bordering the northern and eastern edges of the study area extended further inland than it does today, and contained a complex network of sloughs and tidal ponds – open water features on the marsh plain (fig. 5.7). Wet meadows and alkali meadows formed in the lowlands, creating seasonal wetland habitat. Small patches of alkali marsh and valley freshwater marsh collected in poorly-drained depressions along the edge of the foothills. The wetlands were fed by intermittent creeks flowing from the hills that spread winter flood flows broadly across the flat alluvial plain. This repeated pattern created a fringe of seasonal wetlands bordering the tidal marsh. In the hilly upland portion of ECCC, perennial creeks, springs, and seeps provided year-round sources of water.

In contrast to the rest of ECCC, the northeastern portion of the study area – the alluvial fan of Marsh Creek – almost entirely lacked persistent wetland features. This drier, more well-drained plain (largely occupied by oak savanna and interior dune

Table 5.2. Estimate of total area of historical wetlands. The thirteen historical wetland types are grouped by class. These numbers represent wetland cover in the mid-1800s, as shown by our habitat map. Acreages listed include some areas of tidal marsh within the study area that were outside of the HCP. In most cases, acreages represent a minimum area. This is particularly true for ponds and freshwater marshes – we were almost certainly unable to capture all of the wetland features historically present. Certainty levels indicate uncertainty – H indicates that the mapped acreage is 90-110% of actual size, M is 50-200%, and L is 25-400%. (See table 2.1 for more discussion of certainty levels.) Numbers in this table are rounded to the nearest 10 to more accurately reflect our level of certainty, and may differ slightly from the numbers used for calculations.

Class	Certainty Level	Habitat	Acres
Alkali	L	Perennial Alkali Pond	3
	M	Alkali Marsh	90
	H	Alkali Flat	290
	M	Alkali Sink Scrub	1,970
	H	Alkali Meadow	6,500
Alkali total	M		**8,853**
Tidal Marshland	L	Tidal Slough	100
	L	Tidal Pond	170
	H	Tidal Marsh	22,400
Tidal marshland total	H		**22,670**
Palustrine Wetland	L	Seep Wetland	0.17
	L	Seasonal Pond	0.23
	L	Perennial Freshwater Pond	3
	M	Valley Freshwater Marsh	40
	H	Wet Meadow	4,320
Palustrine total	H		**4,363**
		Total , all wetland habitats	**35, 886**





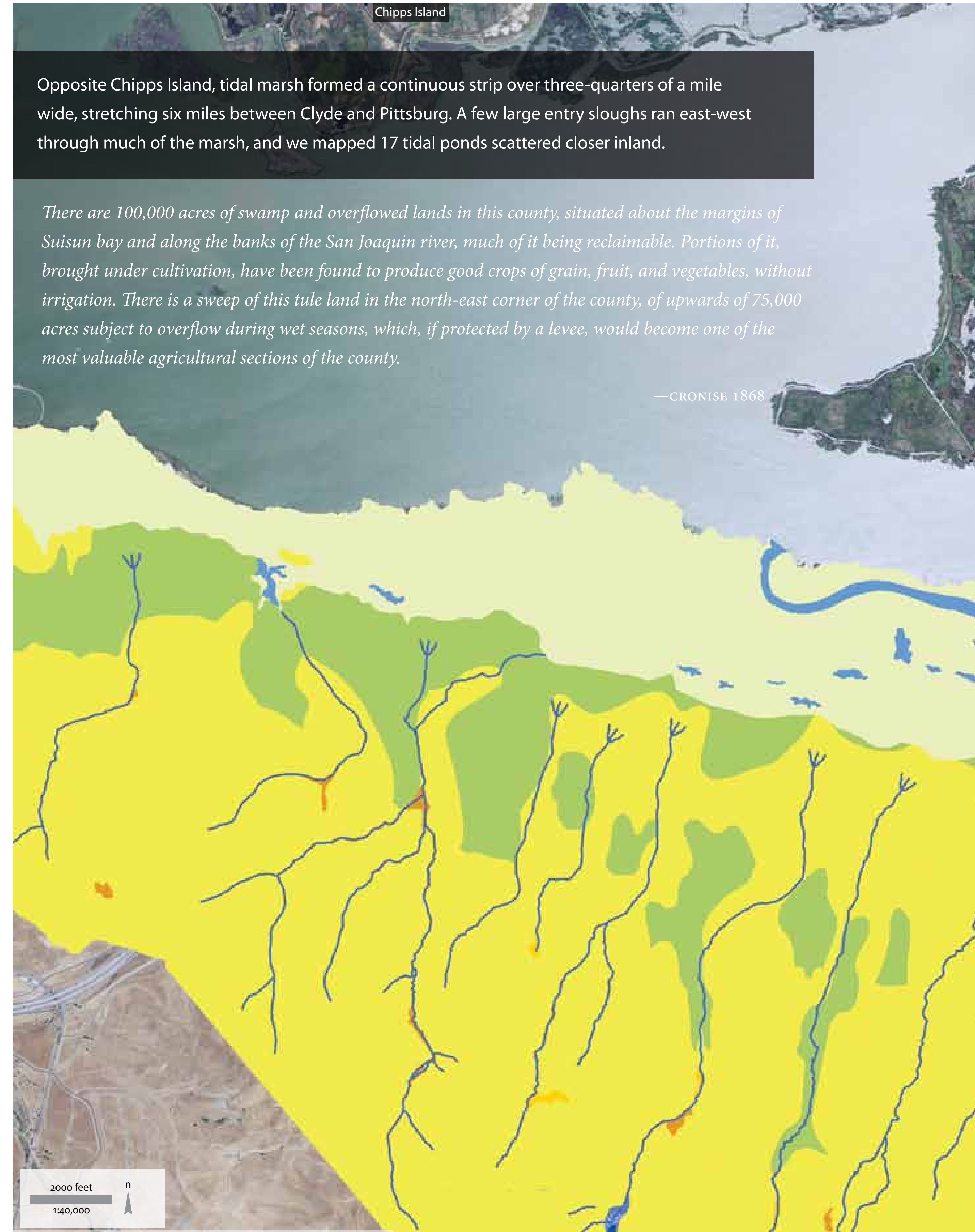
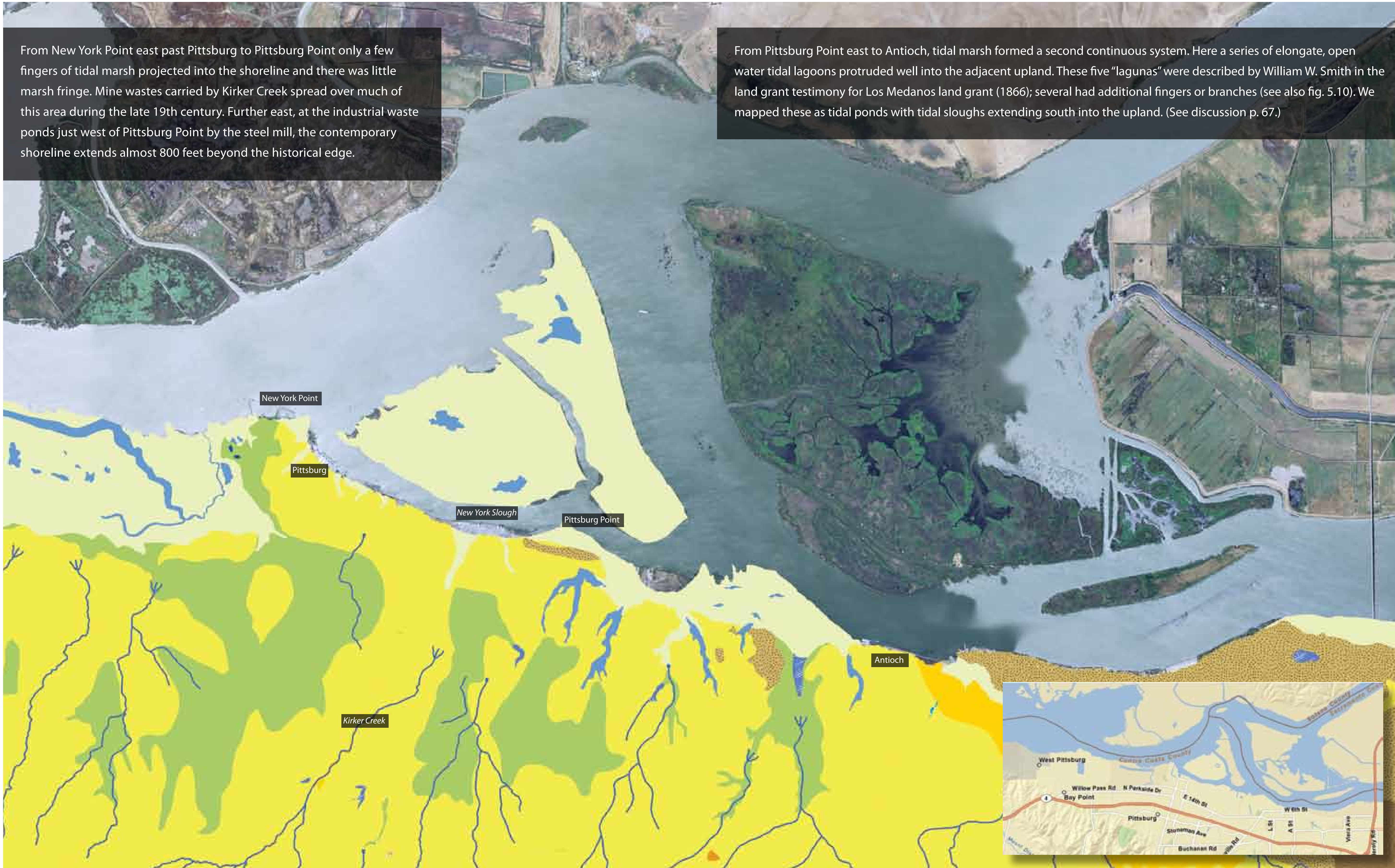


Figure 5.7. Historical tidal marsh – western portion. Tidal marsh shown in pale green, sloughs in light blue. (Background USDA 2009, courtesy of NAIP)

From New York Point east past Pittsburg to Pittsburg Point only a few fingers of tidal marsh projected into the shoreline and there was little marsh fringe. Mine wastes carried by Kirker Creek spread over much of this area during the late 19th century. Further east, at the industrial waste ponds just west of Pittsburg Point by the steel mill, the contemporary shoreline extends almost 800 feet beyond the historical edge.

From Pittsburg Point east to Antioch, tidal marsh formed a second continuous system. Here a series of elongate, open water tidal lagoons protruded well into the adjacent upland. These five "lagunas" were described by William W. Smith in the land grant testimony for Los Medanos land grant (1866); several had additional fingers or branches (see also fig. 5.10). We mapped these as tidal ponds with tidal sloughs extending south into the upland. (See discussion p. 67.)



habitats) stood in contrast to the seasonal wetlands to the west and south. However, Marsh Creek would have occasionally flooded even this dry plain (Eastern Contra Costa Soil Conservation Service et al. 1959).

The most prevalent non-tidal wetland types in the study area were alkali meadow (6,500 acres) and wet meadow (4,320 acres; see table 5.2). Tidal marshes provided an extensive amount of habitat, covering at least 4,200 acres in the north, and an additional large swath in the east – we included approximately 18,200 acres of Delta wetlands in our study area, but this could easily extend further east into the Delta (fig. 5.8). Less common were perennial wetlands, including ponds, freshwater marsh, and alkali marsh, each comprising less than 100 acres.

Wetlands were not distributed uniformly across the study area, but rather exhibited distinct subregional patterns associated with physical controls such as climate, topography, soils, and groundwater. For example, 80% of the wet meadows were found in the northern watersheds, while 60% of the alkali meadows were found in the east. These patterns are discussed further below. In our analysis we found it useful to divide the region by geomorphic unit to reveal subregional patterns (see fig. 2.4). The units were montane (>900 ft), foothills (200-900 ft), and plains (<200 ft).

Tidal Marsh

Before shoreline development, there were 4,200 acres of tidal marsh in East Contra Costa County between Antioch and Clyde (fig. 5.9, see fig. 5.7). Within the Contra Costa County portion of the Delta (between Antioch and the Alameda County line) we include an additional 18,200 acres, extending slightly beyond the HCP boundary to include present-day Discovery Bay (see fig. 5.8). For this project, we depicted channel detail in the northern portion of the tidal marsh, where we have detailed and reliable early sources, but equivalent data were not available for the eastern tidal marshes (fig. 5.10). For more detail on the eastern marshes, see the forthcoming Sacramento-San Joaquin Delta Historical Ecology study (Whipple et al. forthcoming, http://sfei.org/DeltaHEStudy).

The marshes along the north shore were dominated by freshwater characteristics with some saline influences. At Antioch, freshwater was historically available at low tide almost year round in all but the driest summers (Contra Costa Water District 2010). An 1879 county history states that "the water along the San Joaquin frontage is fresh for ten months out of the twelve, and, in most years, is fresh the entire year; even in very dry seasons it is fresh at low water" (Smith and Elliott 1879). Morse (1888) reported that "at Black Diamond [Pittsburg]…the water taken from New York Slough on the last of the ebb tide is used by some for domestic purposes all through the year, though it becomes somewhat brackish in the Autumn." Salt water began to intrude in 1918 due to a drought and increasing upstream water diversions (Contra Costa Water District 2010).

Vegetation was also sufficiently palatable for cattle and sheep grazing. The marshes near Robinson's Landing (subsequently Pittsburg Point) were referred to as pasture (Woodruff 1865, Clark 1865, Marsh 1865). In the mid-1800s stock grazed here and watered at the river even in summer, indicating that the San Joaquin River at this point remained fresh (Stratton 1865b).

While these marshes were often generically described as "tule flats" (Sherman et al. ca. 1849) or "tule swamps" (Smith and Elliott 1879), implying a homogenous zone of tall *Schoenoplectus* (syn. *Scirpus*) *acutus*, vegetation patterns were more complex. Rich early descriptions of this region come from the Los Medanos land grant case. A local shepherd, Sloan (1865), described the marsh vegetation, testifying that "Some call it tule, it grows green grass the year around; it is moist and soft." Woodruff (1865), who raised cattle in the area, described a mix of *Scirpus*, *Distichlis*, *Salix*, and other species: "Some wild grass and willows grows upon these lands and tule and mire *[?]* and salt grass." George Howard Thompson (1868) described, in fairly coarse terms, a similar mix of freshwater marsh vegetation: "it was grass and weeds and some small willow bushes. Fresh water vegetation." Masters (1861) reported "tules and grass" and noted that the "turf" became "broken by cattle traveling over it."

Other evidence suggests that tall tules were also present in this transitional area to the Delta: "On either side of the river, in the immediate vicinity of Antioch, as well as surrounding all the islands in the two rivers, the tule growth is wonderful" (*Antioch Ledger* 1872a). A tule factory operated out of Antioch (*Pacific Rural Press* 1875). In 1865 land grant testimony a property owner stated, "It is Tule land, the whole of it and formerly the tules grew very high – below the roots of the Tule and grass the land is very soft and mucky – many places pools and ponds of water stand during the year, produced by the tides" (Smith 1865). Testimony by Mahan (1861) agrees that in the 1850s "there was a heavy growth of tule bordering on the high lands. It is springy and marshy land as is considered unsafe to go in there with stock." GLO surveyor Loring reported "low boggy marsh with high tule not fit for cultivation" between Mallard Slough and Willow Creek in 1851. Nearby, surveyor Ransom (1851) similarly notes "tules and slough." A surveyor attempting to fix the high water point near Pittsburg commented that "the only definite line is the outer edge of the tule; that line is, in the majority of cases, clear and sharp cut, and is, for all practical purposes, the high water line" (Morse 1888).

It is an utter impossibility to say just where the high water line is. In this survey it was taken as being the inner edge of the tule in cases where there was a line of demarcation between the tule and marsh grass; in others the judgment of the rodman had to be relied upon. No two surveys could possibly agree in the location of this line, even if made by the same person, one immediately after the other.

– MORSE 1888, IN T-SHEET DESCRIPTIVE REPORT #1793

One point in particular we digged [sic] *down with a spade on this ground – some foot 18 inches to the root of the tules where they used to grow – When I first knew it was all tule land. In 1862 and last winter this land and gravel was washed down – as much washed down last winter as any season – also noticed where Wyatt had some ditching done – it had all been filled in with sand washed down.*

—CLARK 1865

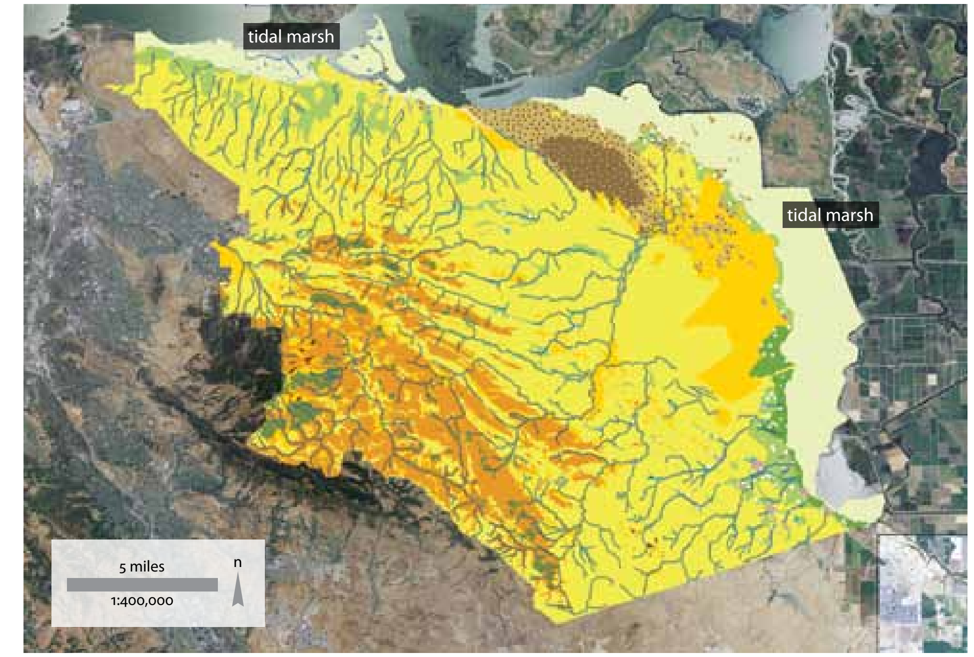
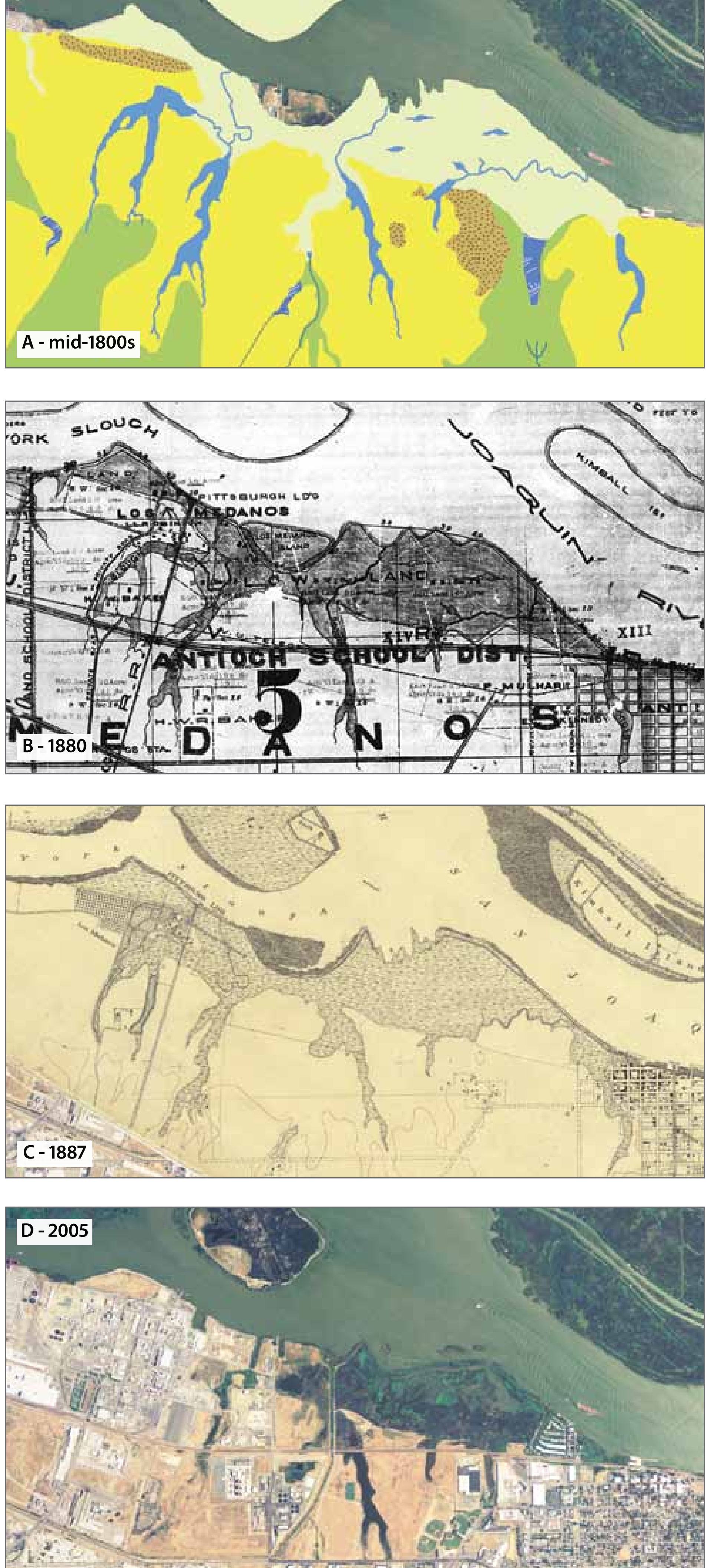


Figure 5.8. Historical tidal marsh. Tidal marsh (pale green) stretched east and south along the border of ECCC to join with the marshes of the Sacramento-San Joaquin Delta. Much of the eastern body of tidal marsh has since been reclaimed and drained – we measure a loss of at least 14,000 acres out of a total of 18,200 acres within our mapped study area. (Background USDA 2005, courtesy of NAIP)

Figure 5.9. Tidal wetlands near Big Break. (Photo May 9, 2009 by Ruth Askevold)



[Q] DID YOU ALSO EXAMINE THE LANDS INCLUDED BETWEEN LEWIS SURVEY OF THE MEDANOS RANCH AND THE SAN JOAQUIN RIVER?
[A] I did.

[Q] WHAT IS THE CHARACTER OF THOSE LANDS?
[A] From the north-east corner of the ranch, for about ¾ of a mile, the high land comes down to the river with a high bank at Antioch. From thence, there is a strip of low land between the river and the highland with an average width of about 150 yards-extending down the river for about 2½ or 3 miles.

[Q] WHAT IS THE CHARACTER OF THESE LOW LANDS?
[A] It is of a low, swampy character. They were not covered by the tides of any time that I was there; excepting two or three small sloughs.

—SURVEYOR GEORGE H. THOMPSON 1868,
TESTIFYING IN MEDANOS LAND GRANT CASE

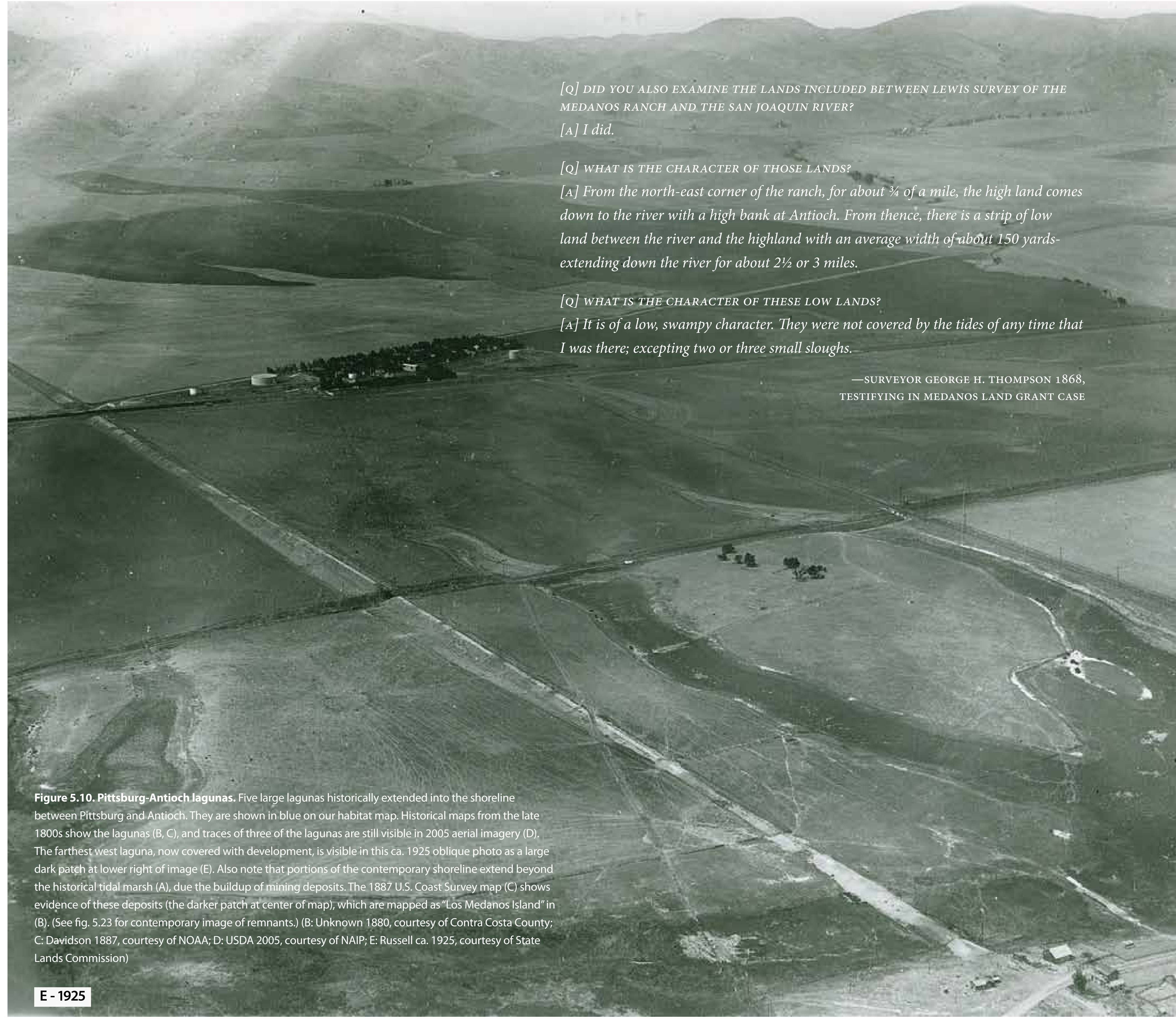


Figure 5.10. Pittsburg-Antioch lagunas. Five large lagunas historically extended into the shoreline between Pittsburg and Antioch. They are shown in blue on our habitat map. Historical maps from the late 1800s show the lagunas (B, C), and traces of three of the lagunas are still visible in 2005 aerial imagery (D). The farthest west laguna, now covered with development, is visible in this ca. 1925 oblique photo as a large dark patch at lower right of image (E). Also note that portions of the contemporary shoreline extend beyond the historical tidal marsh (A), due the buildup of mining deposits. The 1887 U.S. Coast Survey map (C) shows evidence of these deposits (the darker patch at center of map), which are mapped as "Los Medanos Island" in (B). (See fig. 5.23 for contemporary image of remnants.) (B: Unknown 1880, courtesy of Contra Costa County; C: Davidson 1887, courtesy of NOAA; D: USDA 2005, courtesy of NAIP; E: Russell ca. 1925, courtesy of State Lands Commission)

Alkali Wetlands

Alkali wetlands historically covered approximately 8,850 acres (fig. 5.11). Today, roughly 30% (2,720 acres) remain. The decline is largely attributable to the vast areas along the eastern boundary of the plains that were converted to agriculture. Although grain had been grown in this region beginning in the 1860s, intensive irrigation began only in the 1920s, so the alkali extent was likely relatively unchanged at the time of the 1933 soil survey (see p.20). Even today, alkali traces can be clearly seen in the landscape (fig. 5.12). Most alkali areas in the upland drainages, such as those along Brushy Creek, are intact and largely of the same spatial extent.

Alkali wetlands are described in some of the earliest accounts (table 5.3). While these mid-19th century descriptions are not spatially comprehensive, they describe

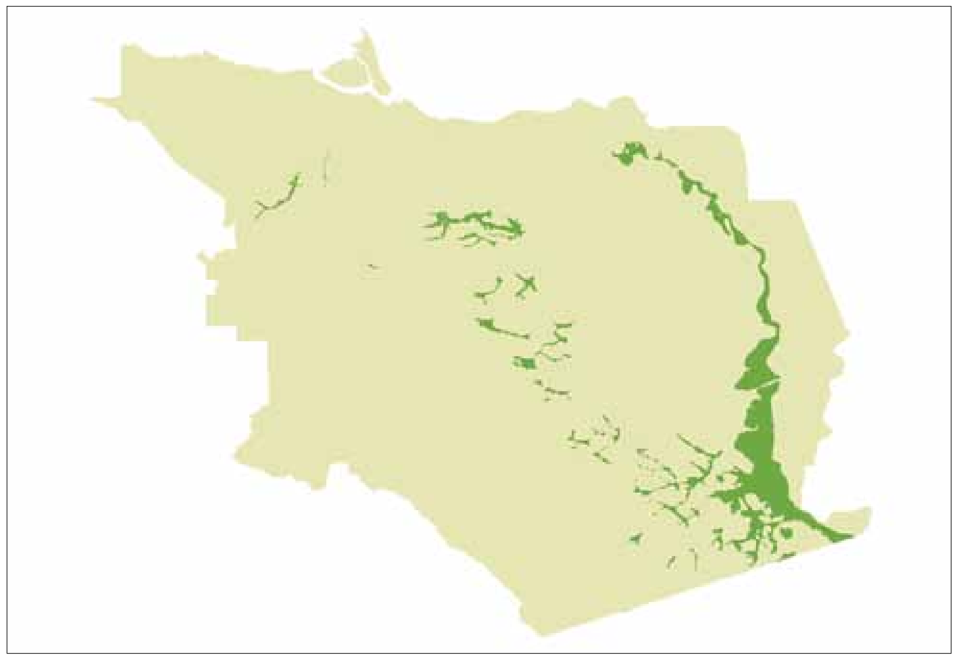


Figure 5.11. Historical alkali extent. The dark green polygons show the alkali habitats of ECCC, which include perennial alkali pond, alkali marsh, alkali flat, alkali sink scrub, and alkali meadow.

Table 5.3. Early accounts of alkali in ECCC.

Observer	Year	Location	Description
Bidwell (traveler)	1841	moving east from the San Joaquin to Marsh's house	"The earth was in many places strong impregnated with salt"
Norris (surveyor)	1851	intersection of Byron Hot Springs Road and Armstrong Road	"The plain has the appearance of being covered with water in the rainy season, and in some is entirely free from vegetation"
Day (surveyor)	1853	southeast Contra Costa	"much alkali," "strong mixture of alkali," "soil 2nd and 3d rate, some alkali mixed with it"
Dyer (surveyor)	1869	south of study area	"soil strongly impregnated with alkaline, and subject to overflow"

Figure 5.12. Impact of alkali on agriculture. Traces of historical alkali habitats are still visible as less fertile patches in this 2005 aerial. Red lines indicate the extent of historical mapped alkali, overlaid on this 2005 aerial near Discovery Bay. The historical alkali swath generally corresponds with a brown, apparently less fertile patch down the center of the image. Contemporary land use mapping indicates that several of these alkali patches remain "grass" or "ruderal" rather than agriculture (Jones & Stokes 2006, Hawkins 2007). Although efforts have been made to reclaim alkali lands through irrigation, in combination with the application of gypsum and other substances to leach salts from the soil, patches like this are a reminder of the persistence of alkali. (USDA 2005, courtesy of NAIP)

alkali in areas that match alkali lands mapped by later soil surveys, showing that these features predated agricultural activity.

Alkali Meadow

We estimate the historical extent of alkali meadow at 6,500 acres. Alkali meadow was historically the most widespread of the four alkali habitat types, and contained smaller patches of pools, alkali sink scrub, alkali flat, and alkali marsh within its borders (Holland 1986).

Alkali meadow followed the lower reaches of Brushy and Frisk creeks, spreading to cover much of the area along the eastern tidal marsh and the San Joaquin River. The alkali in this lowland region stretched in fairly continuous blocks, with one particularly large region near the tidal boundary covering 2,300 acres. Soils included in this region are described were with poor internal drainage and with an "appreciable salt content" (Carpenter and Cosby 1939).

Moving northwest, alkali meadow continued through a series of valleys. Over 2,000 acres (30% of the total alkali meadow) lay along the border between foothill and plains geomorphic units. The largest of these was along East Antioch Creek just north of Lone Tree Valley, under a present-day housing development, and measured almost 560 acres. Remnant patches of alkali in some of the other valleys still remain. For much of the alkali soil mapped through these valleys "internal drainage [was] poor" and soils supported "some species of saltgrass" (Carpenter and Cosby 1939). Similarly, in the 1977 soil survey these patches supported "annual grasses, saltgrass, and some saltbush" and were "subject to ponding" (USDA 1977). Our classification of alkali is further supported by the remnant fragments of alkali grassland mapped in these valleys for the HCP. In the northern part of the study area, these patches of alkali may have been fed in part by alkaline springs, which occurred in the hills (*Antioch Ledger* 1876, Brewer 1974).

Vernal pools with limited vegetative cover may have historically existed within these alkali meadows. Vernal pools occur in clay soils with "hummocky microrelief" (Carpenter and Cosby 1939, Holland 1978, Baye et al. 2000), such as seasonally-filled depressions in the alkali meadows. These features are important seasonal water sources and typically support a number of specially adapted native species. Species of concern that may rely on vernal pools include Brittlescale (*Atriplex depressa*), Recurved larkspur (*Delphinium recurvatum*), San Joaquin spearscale, Adobe navarretia, fairy shrimp, and California tiger salamander (Jones & Stokes 2006, CNDDB 2009).Unfortunately, we were unable to map vernal pool extent using historical sources. However, based on historical soil survey descriptions, vernal pool complexes were likely interspersed across 3,000 acres that were mapped as alkali meadow, or about half of the alkali meadow extent.

Alkali / Valley Sink Scrub

One noteworthy feature in southeast Contra Costa that is largely absent today was a band of alkali sink scrub (or Valley sink scrub; see Holland 1986, Jones & Stokes 2006) that occupied the eastern margin between the alkali meadows and the tidal marsh. This nearly continuous swath of 1,970 acres stretched over seven miles in length. Alkali sink scrub is distinguished by its patchy shrub cover, which stands out in contrast to the lower herbaceous cover of alkali meadow (fig. 5.13b).

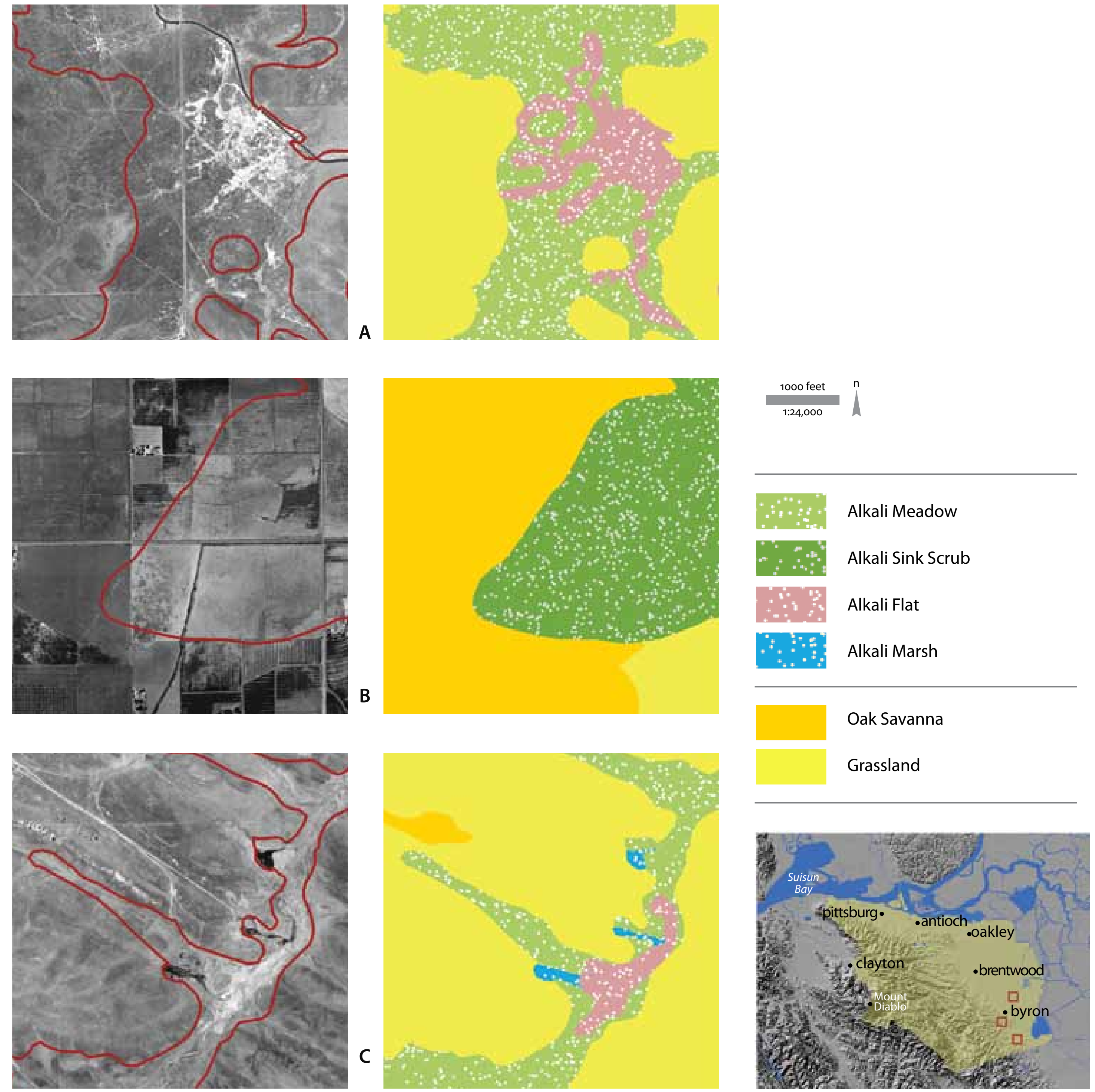
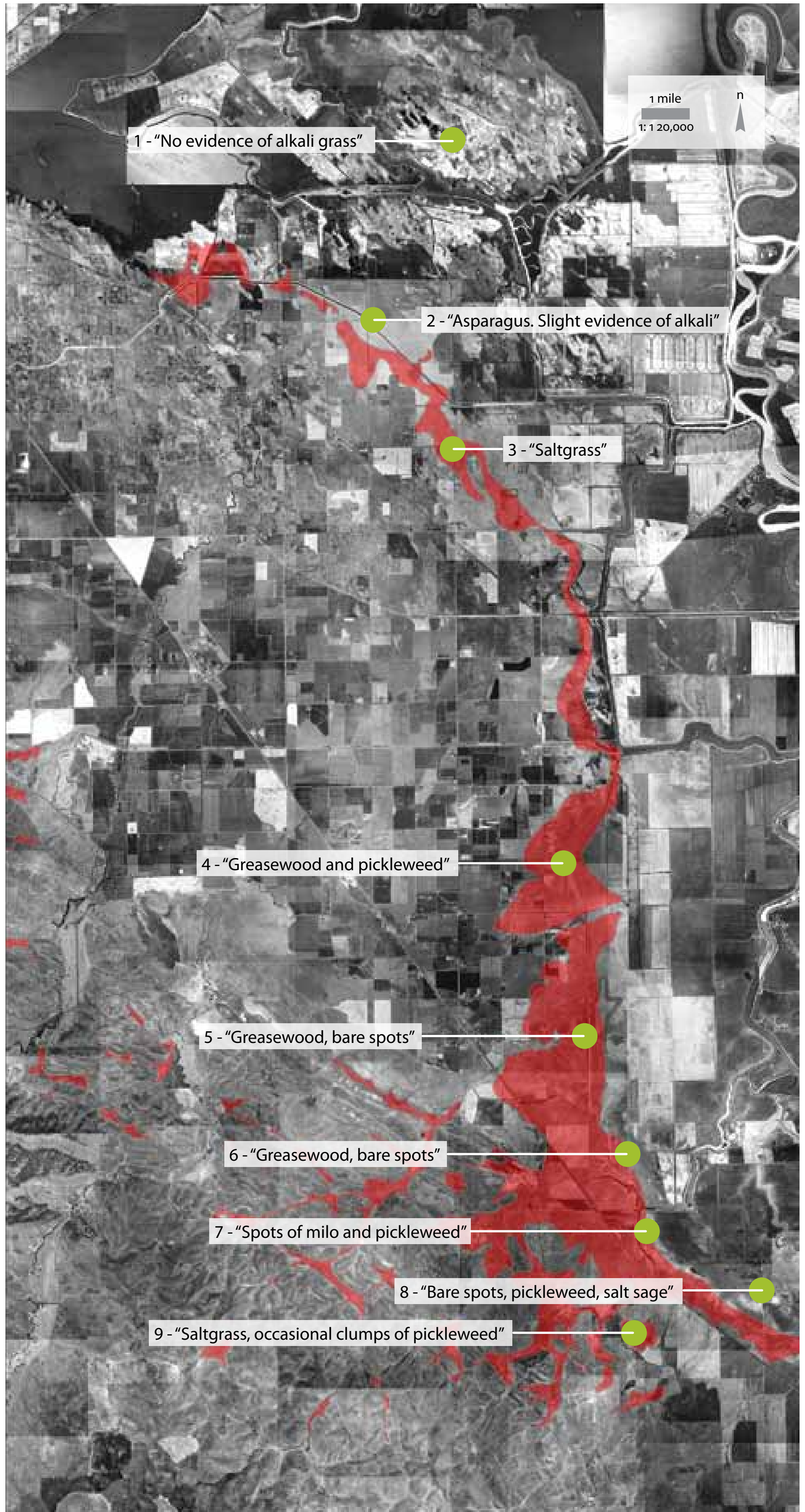


Figure 5.13. Alkali habitat signatures in historical aerials. Red lines on the historical aerials at left trace the extent of historical alkali habitats; these habitats are shown as mapped at right. In the first set of images (A), the bare scalded alkali flat contrasts with the surrounding grasslands and alkali meadows. In the second set of images (B), the speckled pattern of alkali sink scrub is barely visible in the aerial at left, and is represented by the mapped green polygon at right. At bottom (C), dark patches of alkali marsh are visible in the historical aerial as part of alkali complexes including alkali flats and alkali meadows. (USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley)



WHAT IS 'GREASEWOOD'?

Not far from the San Joaquin River, GLO surveyor Ralph Norris noted vegetation he calls 'greasebushes' (1851), while the early soil survey called shrubs in the same area 'greasewood' (Carpenter and Cosby 1939). The term 'greasewood' has been applied to a wide variety of plants over time, but here may refer to iodine bush *(Allenrolfea occidentalis)*, which was often called greasewood (McMinn 1951). Greasewood is also used to refer to other plants, including chamise (*Adenostoma fasciculatum*) and also black greasewood *(Sarcobatus vermiculatus)*, which grows on the alkaline clay soil of desert valleys and is not found in this area (Hickman 1993). We found references linking greasewood to chamise, pickleweed, and iodine bush (Jepson 1911, McMinn 1951). Regardless of the exact species that the GLO or USDA soil survey encountered, the survey notes suggest a band of salt-tolerant shrub cover.

Iodine bush is a halophyte – able to grow in very saline soils – and grows in association with other salt-tolerant plants, including San Joaquin spearscale *(Atriplex joaquiniana)*, brittlescale *(Atriplex depressa)*, and bush seepweed *(Suaeda moquinii)* (Jones & Stokes 2006).

Figure 5.14. Alkali vegetation and soil samples. The 1939 soil survey report included an analysis of salt content at nine points in "salt-affected soils" along the eastern border of the county, which are excerpted at left. All nine of these points fall within alkali habitats (shown in red) or the historical tidal marsh (directly to the east of the red area). See accompanying Table 5.4 for more details. Note the descriptions of greasewood and other salt-tolerant vegetation. (Carpenter and Cosby 1939)

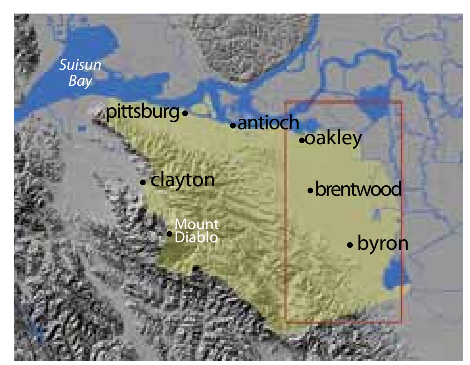


Table 5.4 Characteristics of salt-affected soil samples from the 1939 soil survey. Soil horizon refers to the layer of soil, working from the surface soil (A) to subsoils and parent material (B and C). (Carpenter and Cosby 1939)

Site #	Vegetation and Character of Land	Crosswalk: common and Latin name	Kind of Soil / Horizon	Total Salts Percent/ Horizon	Average in 6 foot section
1	"No evidence of alkali grass"	Alkali grass (saltgrass or *Distichlis spicata)*	Loamy sand / A Sand / B Sand / C	.02 / A .02 / B .02 / C	.02
2	"Asparagus. Slight evidence of alkali"	Asparagus (cultivated crop)	Clay / A Clay / B Clay / C	.36 / A .18 / B .18 / C	.24
3	"Saltgrass"	Saltgrass = *Distichlis spicata*	Clay / A Clay / B Clay / C	.225 / A .775 / B .31 / C	.44
4	"Greasewood and pickleweed"	Greasewood (probably iodine bush or *Allenrolfea occidentalis)* Pickleweed = *Salicornia*	Clay / A Clay / B Silty Clay Loam / C	.075 / A .60 / B -- / C	.34
5	"Greasewood, bare spots"	Greasewood (probably iodine bush or *Allenrolfea occidentalis)*	Loam / A Clay / B Clay Loam / C	.60 / A .95 / B -- / C	.78
6	"Greasewood, bare spots"	Greasewood (probably iodine bush or *Allenrolfea occidentalis)*	Loam / A Clay / B Clay / C	1.16 / A 1.18 / B 1.14 / C	1.16
7	"Spots of milo and pickleweed"	Milo (Sorghum, cultivated crop) Pickleweed = *Salicornia*	Loam / A Clay Loam / B Clay Loam / C	1.00 / A .96 / B 2.50 / C	1.49
8	"Bare spots, pickleweed, salt sage"	Pickleweed = *Salicornia* Salt sage = *Atriplex*	Clay / A Clay / B Clay / C	.88 / A 1.16 / B .55 / C	.86
9	"Saltgrass, occasional clumps of pickleweed"	Saltgrass = *Distichlis spicata* Pickleweed = *Salicornia*	Loam / A Clay / B Clay Loam / C	.25 / A .14 / B -- / C	.20

Alkali sink scrub may have had a much larger extent than the almost 2,000 acres we were able to map. The mapped regions show a tight correspondence with Marcuse clay soil (Carpenter and Cosby 1939), which extends north along the marsh boundary for the entire eastern edge of Contra Costa County. Alkali sink scrub may likewise have continued much further north along this soil type, extending in a thin band up to the northern boundary of Contra Costa County. We were unable to find any other supporting evidence of sink scrub extending this far north, so we did not map to the maximum possible extent.

After we had mapped alkali sink scrub, we compared our mapped polygons with soil salinity samples and their accompanying descriptions from the early soil survey (Carpenter and Cosby 1939; fig. 5.14, table 5.4). At three of the four points within alkali sink scrub, the soil survey noted the presence of "greasewood," and described the soil type as affording "scant pasturage" with a cover of pickleweed, greasewood, saltgrass, "and other more or less salt-tolerant plants" (Carpenter and Cosby 1939). These shrubby plants support our mapping of sink scrub and indicate the presence of alkali. The 1939 soil survey also notes the presence of greasewood (Carpenter and Cosby 1939). Further confirmation comes from GLO: in 1851 Surveyor Norris describes passing through "greasebushes," likely a salt-tolerant shrub (fig. 5.15, see box on opposite page).

The HCP notes the presence of small patches of alkali sink scrub, but groups these with alkali grassland due to their scarcity and small size (Jones & Stokes 2006).

Much of alkali sink scrub was likely converted to alkali meadow through grazing (and potentially due to lowering groundwater table as the land was cleared – see Jones & Stokes 1989); in fact, "conversion of the alkali sink scrub to cultivation has been so extensive that the ecological community has been virtually extirpated" (Freas and Murphy 1988; see also Holland 1986, Jones & Stokes 1989). Grazing can also reduce alkali sink scrub to near ground level, making it challenging to identify this habitat type from aerials (Bartosh pers. comm.).

Alkali Flat/ Alkali Playa

Alkali flats (or playas, see Holland 1986) are seasonal ponds or lakes, filling during wet periods and then drying to salt beds for much of the year. Alkali flats have little to no vegetation, with wide spacing between shrubs and salt crust on the surface (Holland 1986). Characteristic alkali flat species include iodine bush *(Allenrolfea occidentalis)* and *Atriplex* spp. (Holland 1986). An excellent description of alkali flat comes from surveyor Sherman Day, just south of the Contra Costa county line: "vegetation upon it appears thin, and some spots are quite bare as if water soaked at times" (Day, August 1853).

To map alkali flat we traced areas with the distinct aerial signature of unvegetated, seasonally flooded tidal ponds or flats. Alkali flats appear bare of vegetation and white in aerial photography, so they were relatively easy to identify (see fig. 5.13a).

We mapped 290 acres of alkali flats, all concentrated in the southeastern portion of the study area. These were areas that we could identify from the historical soils map and 1939 aerial, some of which had been partially covered or developed by 1939. Many of the alkali flats still exist today and were classified as alkali wetland in the HCP (Jones & Stokes 2006). We identified a number of additional areas—a few were historically contiguous with the existing patches while others were in separate areas close to the Delta margin. Patches of alkali flat surrounded Byron, with the two largest patches (each measuring 57 acres in extent) at Byron Hot Springs and just south of the Byron airport. These areas appear largely unchanged between 1939 and 2005 in aerial photographs.

General Land Office surveys confirm the interpretation of alkali flat within the study area as well. Near the present-day Bryon airport GLO surveyor Norris encountered a large bed of alkali flat that is still present today. He noted entering a "flat…encrusted with salt," "dry bed of salt pond," and "low flat encrusted with salt" (Norris October 1851), as he repeatedly crossed the branching arms of this alkali flat.

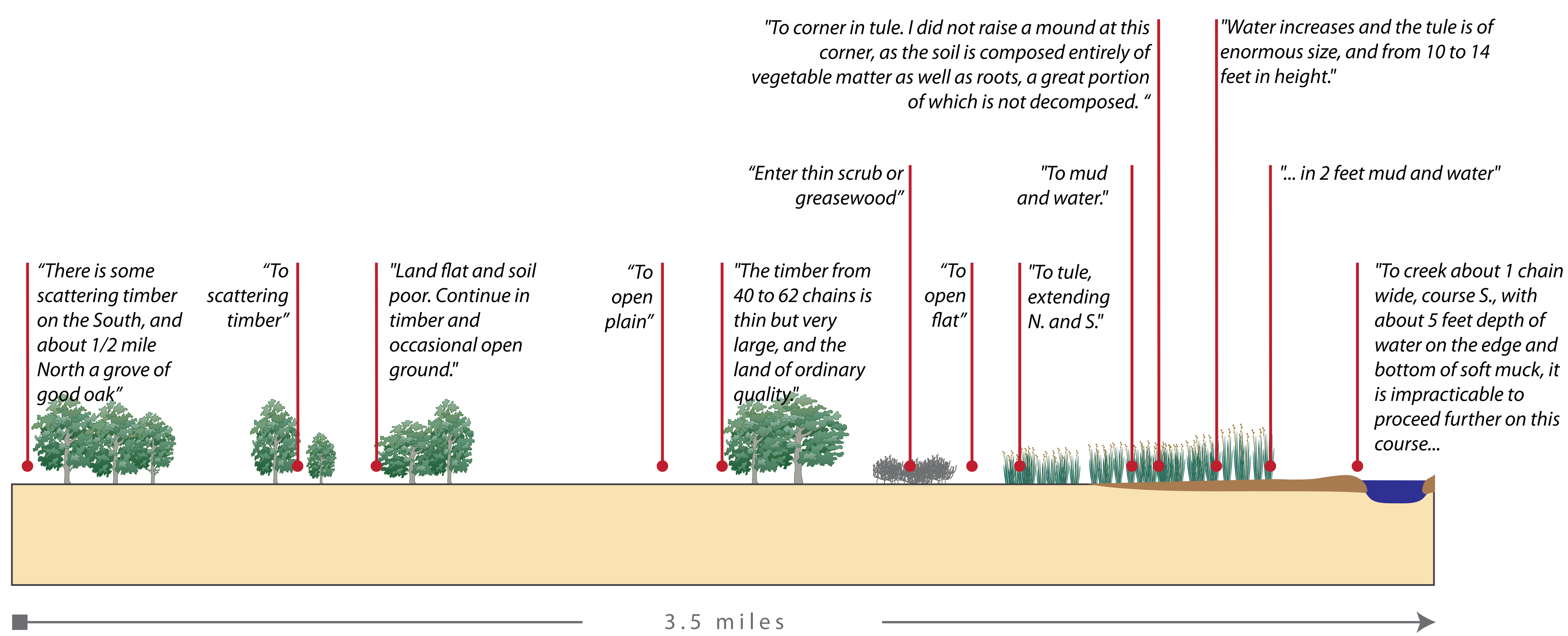
Alkali Marsh

Historically, alkali marshes occurred in small patches throughout southeastern Contra Costa, as well as along the border of some streams running through alkali meadow (Jones & Stokes 1989; see fig 5.13c). We identified a historical extent of 90 acres of alkali marshes, primarily in the southeast. Alkali marshes often existed as part of larger complexes containing alkali meadow, flat, and/or sink scrub. Today alkali marsh is extremely rare – the CNDDB records only four occurrences, including the area around Byron (CNDDB 2010).

The name 'greasewood' is rather indefinite, for it does not mean the same plant in all places. However, all the shrubby plants which we know under the name are to be found on soil too alkaline to grow crops until part of the alkali is washed out. Unless one is prepared to reclaim the land by deep drainage so that either rainfall or irrigation or both can wash out the alkali, it does not mater much whether you kill the greasewood or not.

—PACIFIC RURAL PRESS 1919

Figure 5.15. GLO survey transect through alkali habitats. On October 4, 1851, Surveyor Ralph Norris surveyed a line extending east from Kellogg Creek Road to just south of Discovery Bay. He passed through oak savanna, then entered a patch of alkali sink scrub before eventually reaching the tidal marsh and then open water. (Norris 1851, courtesy of the Bureau of Land Management)



Palustrine Wetlands

Wet Meadow

We estimate that approximately 4,320 acres of wet meadow existed historically in ECCC. Most of these wet meadows were found along the northern drainages immediately adjacent to the tidal marsh, but smaller areas also occurred along Kellogg, Sand, and Marsh creeks. Over 95% of total historical wet meadows were found in the plains geomorphic unit, with the remainder in the foothills.

Between Bay Point and Antioch, wet meadow covered over 3,600 acres of the alluvial plain. The many small hill drainages funneled water from the foothills towards the tidal marsh and spread sediment and water into these seasonal wetlands (fig. 5.16). Ambrose adobe clay had a "heavy clay surface soil" that "crack[ed] badly to a depth ranging from 2 to 3 feet when dry" (Carpenter and Cosby 1939). Antioch loam became "boggy" in wet years so that "crops drown out on the flatter areas" (Carpenter and Cosby 1939). Olcott loam similarly became "boggy following heavy rains." Soil moisture patterns indicative of seasonal wetlands can be seen in the 1939 aerial imagery in several undeveloped places on these soil types.

Additional evidence for these seasonal wet meadows came from GLO surveyor Sherman Day. He described "low bottom swampy, overflowed during wet season," "ravine," and "depression" while working westward in 1853 from Antioch towards the current Los Medanos Wasteway.

In addition to these wetlands along the San Joaquin River, small patches of wet meadow extended south across the study area near creeks at the edge of the foothills. North of the Antioch Reservoir was a 230 acre patch of wet meadow between East and West Antioch creeks south of Highway 4. There was an almost 280 acre patch of wet meadow connecting the distributary of Sand Creek with Marsh Creek, and an additional 46 acres of wet meadow along the double channel of lower Marsh Creek. Wet meadows also existed in the foothills along Kellogg Creek and its tributaries in both the upper and lower reaches of the creek, totaling over 150 acres.

Perennial Wetlands

We documented approximately 40 acres of historical perennial ponds and valley freshwater marsh in ECCC. Perennial wetlands occurred along wet meadows, creeks, and springs, as part of larger wetland complexes. There were undoubtedly additional small perennial wetland features that we were unable to map, which may have occurred near mapped seeps and springs.

Small valley freshwater marshes were scattered through ECCC, totaling 37 acres in area. We mapped three small valley freshwater marshes along Frisk and Brushy creeks. Surveyor Sherman Day noted crossing a "tulare spring" and "tulare run" while passing by these marshes in July of 1853 (fig. 5.17).

Other valley freshwater marshes bordered wet meadows in the northern region of ECCC, occupying depressions near the tidal marsh. One valley freshwater

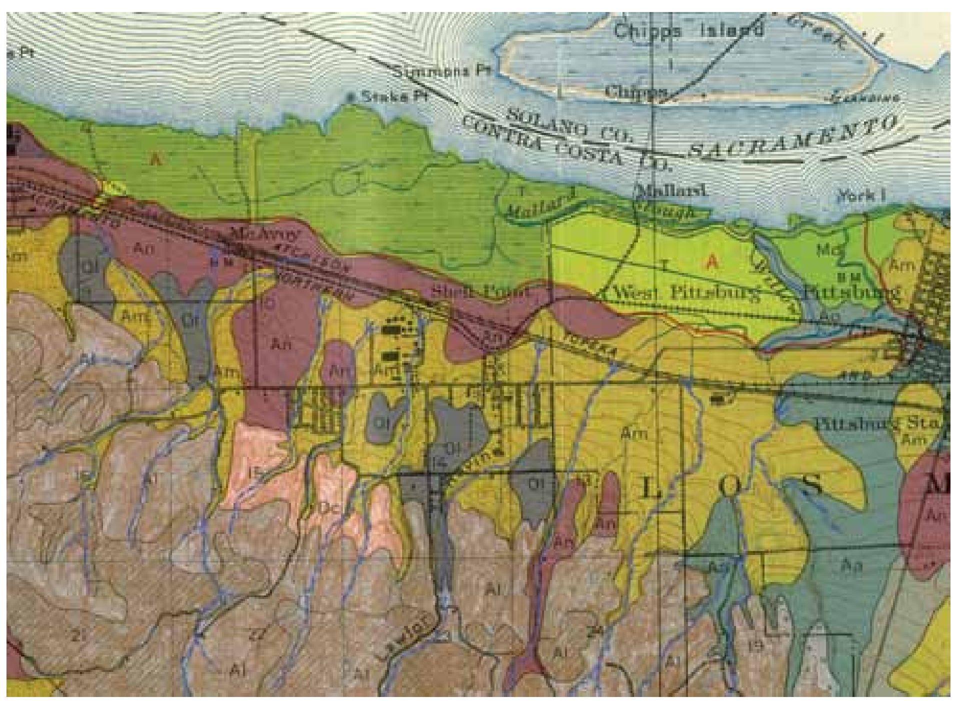
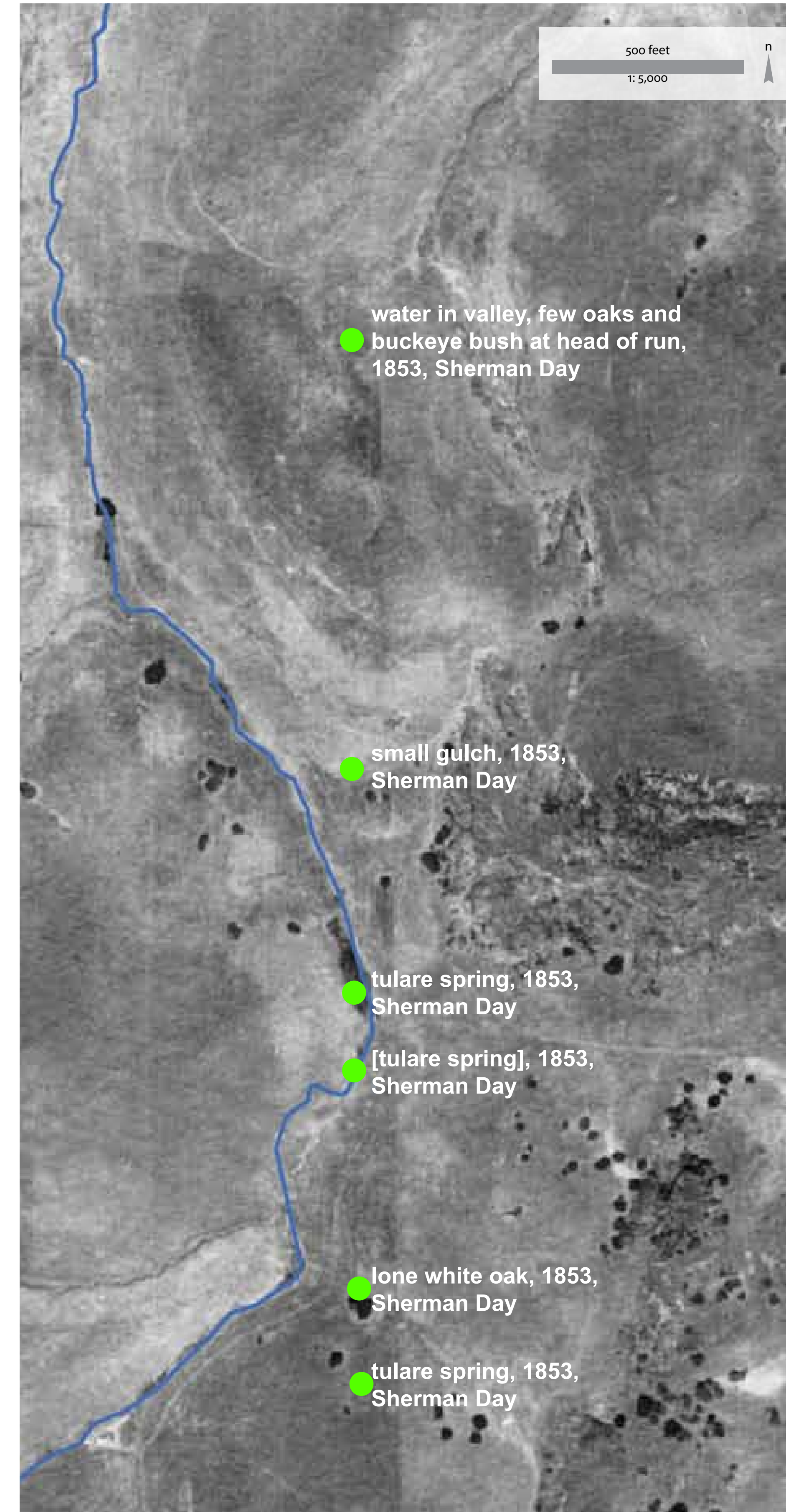


Figure 5.16. Wet soils on the historical soil survey helped us identify potential wet meadows. This portion of the 1933 soil survey just west of Pittsburg shows several wet soils, including Antioch loam (An, purple), Olcott loam (Ol, dark blue), and Ambrose adobe clay (Aa, lighter blue), all of which were used to map wet meadow. The historical creeks we mapped are overlaid here on the soils map and show how the many small creeks drained into these wet soils. (Carpenter and Cosby 1933)

Figure 5.17. GLO survey points describing springs along a tributary to Brushy Creek. As Surveyor Sherman Day worked his way south along a tributary to Brushy Creek near Vasco Caves in July of 1853, he noted springs and "tulare springs" a number of times. One of the tulare springs corresponds with a dark area in the 1939 aerial photograph, suggesting a persistent freshwater wetland. The photo at left shows a wetland along a tributary to Kirker Creek in northern ECCC, another area with wetlands. (Day 1853, courtesy of the Bureau of Land Management; USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; photo July 14, 2011, by Scott Hein, www.heinphoto.com)



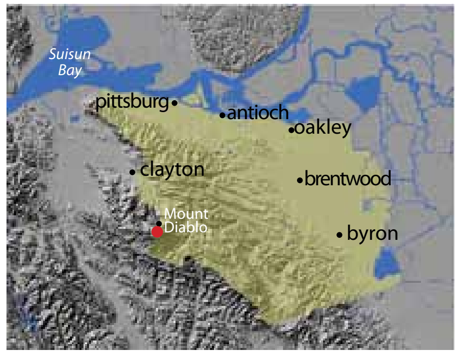
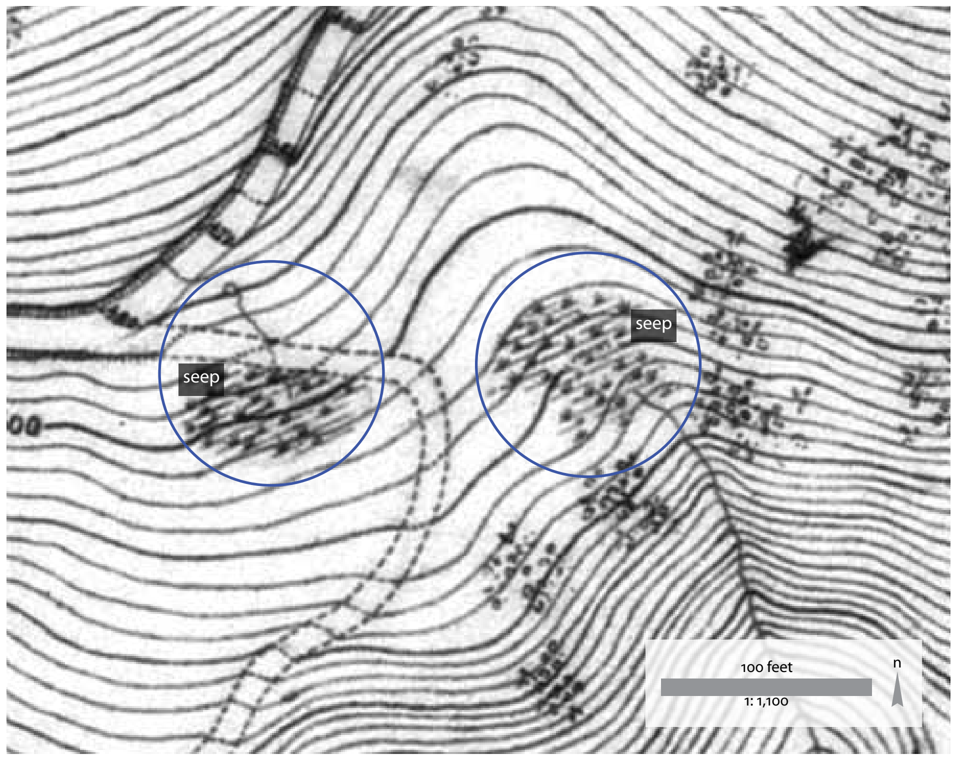


Figure 5.18. Seeps near Mount Diablo. This 1880 map near the peak of Mount Diablo shows small patches of marsh (indicated by the shaded patches) supported by seeps (low-flow springs). Both seep-wetland complexes shown here measure less than a tenth of an acre. At bottom, image of Mount Diablo. (Davidson 1880, courtesy of NOAA; photo October 24, 2009 by Scott Hein, www.heinphoto.com)



marsh shown on the 1887 Coast Survey T-sheets extended west from a wet meadow (Davidson 1887). Along the upper reaches of Lawlor Ravine, by the Concord Naval Weapons Station, a valley freshwater marsh measured over 6 acres in area and surrounded a perennial pond (Jones & Stokes 2006; see fig. 5.6c). This wetland is clearly visible in the historical aerial photos from the dry summer of 1939, and was mapped as an open water pond in 1896 (USGS 1896 (Mount Diablo)).

We mapped a total of 55 springs and seeps in the study area; 45 came from USGS contemporary quads, while the remainder came from a variety of historical maps (fig. 5.18). This represents only a fraction of the springs and seeps historically present in the study area, but likely captures many of the more prominent springs. Only four springs were mapped in the lowlands, with the remainder split evenly between the foothills and uplands.

Perennial ponds in ECCC existed as areas of open water within larger wetland complexes. We mapped four perennial freshwater ponds, totaling 3 acres, all of which were part of a larger wet meadow or valley freshwater marsh complex.

We also compared stock ponds mapped today with those visible in 1939 (USDA 1939, USDA 2005, Jones & Stokes 2006). Of 406 ponds visible in 2005, we found evidence for fewer than 30 in the 1939 historical aerials (fig. 5.19). Some of these contemporary ponds were constructed at sites that were seasonally or even perennially wet historically, but most were simply created along creeks and had no historical precedent (fig. 5.20). Stock-raisers were encouraged to construct these ponds to ensure water for their cattle and sheep through a larger portion of the year. Over half of these stock ponds are concentrated in the foothills, with the remainder divided between montane and plain regions. Constructed ponds and reservoirs add greatly t o the area of contemporary wetland cover.

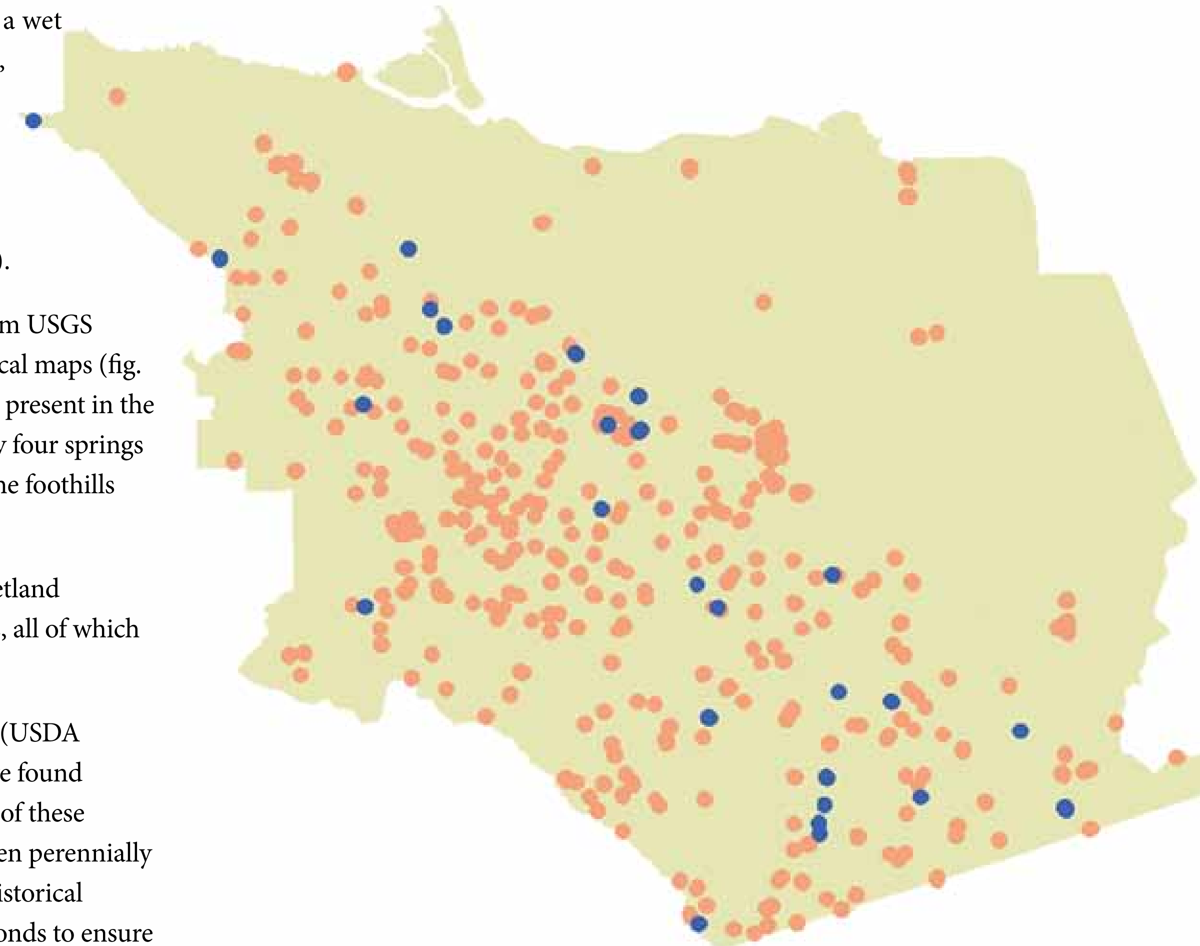


Figure 5.19. Stock pond distribution: 1939 and 2005. We checked for each pond mapped by the HCP in the 2005 and 1939 aerial photos. The diagram above shows ponds that were visible in the aerials only in 2005 (in red) and both in 2005 and 1939 (in blue). Stock ponds in the montane and foothill regions have rapidly multiplied since 1939. Ponds are shown at a much exaggerated size so that they are visible at this scale.

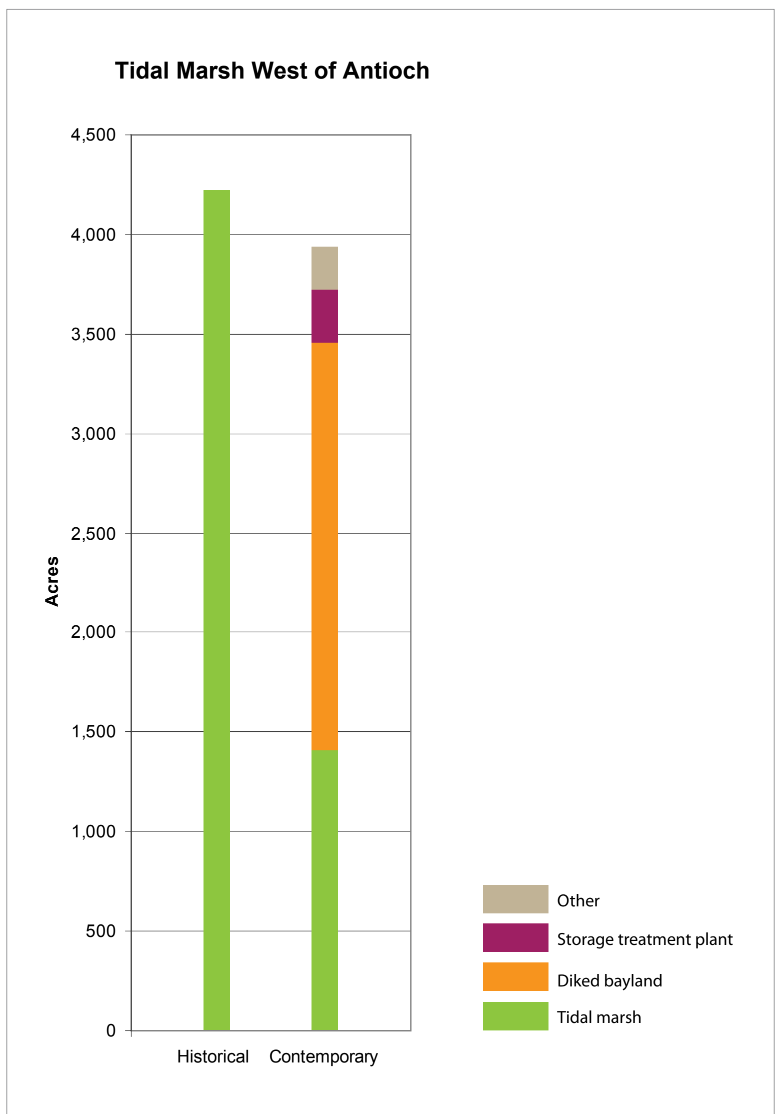
Figure 5.20. Many stock ponds have been constructed since 1939, some on top of historical wetlands. The stock ponds seen in the contemporary photo at right are outlined in red on the 1939 aerial shown at left. These paired photos show both a stock pond constructed on a potential historical wetland along a creek (at top), and a stock pond in a an area with no evidence of historical wetland characteristics (at bottom). (USDA 1939, courtesy of Contra Costa County and the Earth Sciences & Map Library, UC Berkeley; USDA 2005, courtesy of NAIP)

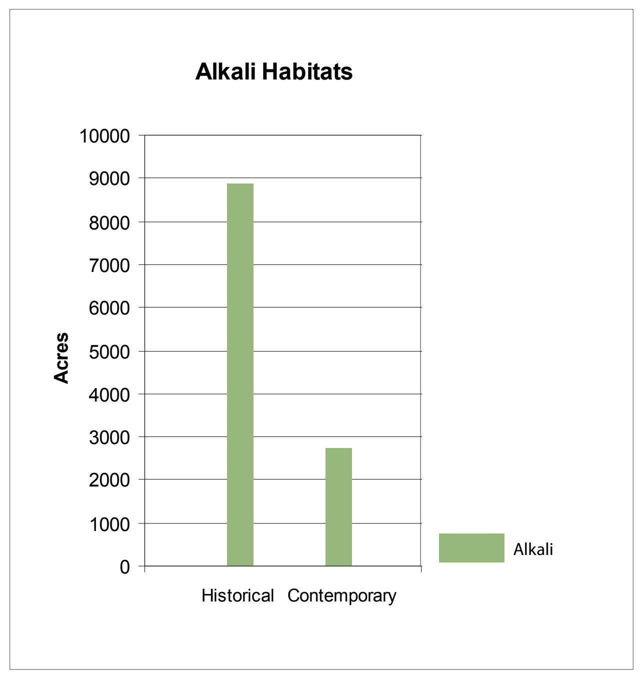
Habitat Changes

Our analyses reveal a dramatic decrease in the extent of tidal marsh. Tidal marsh along the north shore (west of the Antioch Bridge and Oakley) decreased from approximately 4,400 acres in the mid-1800s to 2,100 acres in 2006, a decline of more than 50%. Compared to the overall San Francisco Bay regional tidal marsh decline of 83% (Goals Project 1999), relatively more has been preserved locally. However, 40% of this contemporary tidal marsh is "muted tidal marsh": tidelands that were at one time closed off by levees, and now have limited tidal action (fig. 5.21). East of the Antioch Bridge our contemporary source (Hawkins 2007) is less detailed. However, within the 18,264 acres of historical tidal marsh mapped in this region, the total "native vegetation" mapped in the contemporary vegetation map is only 4,048 acres, or 22% of the historical tidal marsh extent. By visual inspection of the aerials, we would estimate even less than 20% of the historical extent to be covered with tidal marsh.

Nontidal (palustrine and alkali) wetland features showed a similar pattern of decline. The HCP mapped a total of 5,661 acres, representing 3.3% of the study area. We were able to identify over 13,220 acres of these non-tidal wetlands in the historical habitat map, covering 7% of the study area. Because we likely missed many smaller features, the historical mapping should be considered a conservative representation of the historical wetland extent.

The types of nontidal wetlands present in historical and present-day ECCC differ dramatically. In addition to the decline in total area, there has been a shift in wetland type, from temporally dynamic, seasonally active marshes and wet meadows to perennial open water features. In particular, the 3,520 acres of wet meadow (80% of total mapped historical palustrine wetland) that fringed the northern edge of the study area have been replaced with urban development and are no longer mapped today. However, many of the natural and man-made wetland features present today are remnants of historical wetlands. We find that over one-fifth (22%) of the ponds, wetlands, and reservoirs mapped by the HCP overlap with historical alkali and freshwater wetlands in our historical mapping, albeit with a different hydrologic regime today.





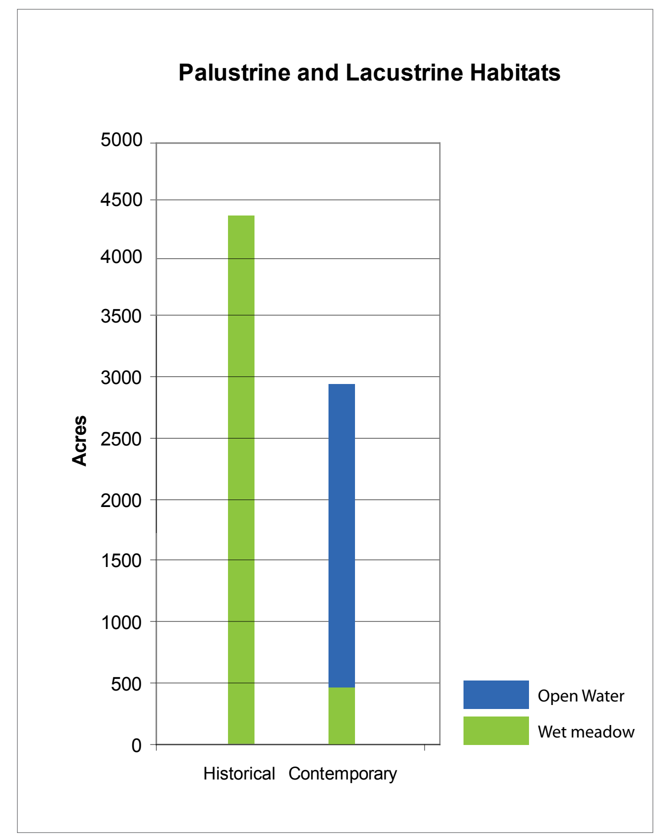


Figure 5.21. Comparison of historical and contemporary wetland habitats. These graphs compare historical and contemporary wetlands to show some of the changes since the mid-1800s. A) We focused on tidal marshes west of Antioch, as this was where we had the best data. The category "tidal marsh" includes tidal ponds, flats, sloughs, and (contemporary) muted tidal marsh. Tidal marsh area declined by more than 50%, with most of the former tidal marsh converted to diked bayland today. Declines in tidal marsh area east of Antioch are even more extreme. B) Alkali habitats include alkali meadow, alkali sink scrub, alkali flat, alkali marsh, and perennial alkali pond, all of which are mapped as alkali grassland and alkali wetland by the HCP. It was not possible to make a crosswalk between these land cover types, so we show the sum of all alkali types here. C) Palustrine and lacustrine wetlands are divided into open water (including ponds, reservoirs, and aqueducts) and marshes and seasonal wetlands (including wet meadow, valley freshwater marsh, and seep wetland, as well as the HCP classes of wetland and seasonal wetland). Historical open water habitats total fewer than 7 acres and are too small to see on the graph. Since the mid-1800s, some of this wetland area has been lost, but perhaps more significantly, wetlands have converted from marshes and seasonal wetlands to perennial open water features such as reservoirs. (Contemporary comparison data from Jones & Stokes 2006 and SFEI 1998)

DISCUSSION

In ECCC, historical analysis identifies a number of wetland habitat types, specific features, and areas of potential restoration opportunity. In addition, these data show some significant ways the historical wetland landscape has been altered, raising questions about the best approach to maintain viable habitats for endangered and/or threatened species. These topics are discussed further below.

Tidal Marsh-Upland Transition Zones

Throughout the San Francisco Estuary, tidal marsh extent has declined by 83% during the historical period (Goals Project 1999). With projected sea level rise, there is significant concern that existing tidal marshes may be lost if they are unable to adjust to new water levels (fig. 5.22). One of the ways tidal marshes naturally persist during times of sea level rise is by migrating inland into adjacent low gradient valleys and plains. However, these ecotones are presently rare because of development along the upland border of marshes. Regional agencies such as the California Coastal Conservancy and Bay Conservation and Development Commission (BCDC) have recognized the identification and protection of these areas as an important component of climate change response.

In ECCC some significant opportunities exist for restoration of these marsh-upland transition zones. ECCC contains some areas of tidal marsh adjacent to farmland or undeveloped land which have potential for future conservation efforts. These include relatively small areas such as the undeveloped grasslands around Dowest Slough, and larger, currently agricultural areas east of Byron and near Dutch Slough at the mouth of Marsh Creek (see Cain et al. 2004). In addition, ECCC contains a rare tidal marsh-alkali meadow ecotone, which historically stretched along the eastern border of the county. Portions of this transitional zone are still intact today, and could be potential areas for conservation. Such areas are currently rare around San Francisco Bay and can provide an array of distinct ecological functions for rare plants (Baye et al. 2000) and other species (e.g., salt marsh harvest mouse high-tide refuge).

Pittsburg-Antioch 'Lagunas'

The series of lagoons along the shoreline between Pittsburg and Antioch represent a locally and regionally unusual feature. While tidal ponds (also known as pannes) were common in tidal wetlands throughout San Francisco Bay (Goals Project 1999), elongated natural lagoons were not. Historical data consistently described substantial, apparently perennial, surface water in these lagoons; some accounts suggested blockage by sand berms (i.e., Smith 1866; see fig. 5.10).

Because of their proximity to the Sacramento-San Joaquin River and connection to adjacent Contra Costa drainages (including adjacent seasonal and in some cases perennial wetlands), the lagoons may have provided year-round (or nearly year-round) open water habitat. They connected to the Sacramento-San Joaquin River only at high tides or times of flood. These features could have supported a number of native species of concern, including red-legged frog, Western pond turtle, and small fish. They would have historically contained largely fresh water; even as far west as Pittsburg local residents were able to rely on the river for freshwater supply as late into the early 1900s (Rowland 1967).

The unusual elongate, inland extension of these features has left several significant remnants. Dowest Slough is a remnant lagoon, as is the body of water to the east, near the Babe Ruth baseball fields (fig. 5.23). These features are now largely disconnected from tidal action but may have potential for restoration. In the case of Dowest Slough, there is potential for a natural tidal marsh-upland transitional zone (see above).

"Point of Timber" Pond

On the east shore of ECCC was another tidal pond, likely similar in origin to the lagunas. This nine acre tidal pond was located near alkali meadow slightly upslope of

Figure 5.22. Tidal marsh and projected sea level rise. The contemporary aerial imagery is overlaid with the historical habitat map (top) and projected 1.5 m sea level rise at a one-year flood level (bottom). Rising sea levels would potentially cover much of the historical tidal marsh extent, drowning remnant tidal marsh. To preserve some tidal marshes and their many ecosystem functions, it will be increasingly important to develop protection strategies for tidal marsh-upland transition zones. (USDA 2005, courtesy of NAIP; Knowles 2010)

Figure 5.23. Dowest Slough and tidal marsh remnants. Tidal marsh remnants such as these along Dowest Slough and the Contra Costa Canal Spillway may offer potential for restoration. These remnants occupy the sites of two of the five historical lagunas between Antioch and Pittsburg. (Photo by Abigail Fateman, CCC)

the tidal marsh margin, near present-day Discovery Bay. The pond can be identified in early USGS mapping (1913 (Woodward Island)) and aerial photographs (Russell ca. 1925), and maintains the same shape and position today (fig. 5.24). Tidewaters likely reached the pond only at the very highest tides, perhaps a few times a year. Water remained trapped in the pond, which appears to have been associated with the small natural sand hill forming its southeastern margin, an extension of the Oakley Sands (see p. 92). While this feature currently persists in a modified form, the land around it may be developed in the future. Adjacent buffers may be important to preserve or enhance its ecological function.

Alkali Wetlands

The conservation and restoration of alkali wetlands is a priority in the HCP (Jones & Stokes 2006). This goal is supported by the findings of this study, which indicate that almost 60% of alkali habitat has been lost in the study area. Areas within the historical extent of alkali wetlands may have potential for restoration, as landscape position, poor drainage conditions, and high salt soil content can be relatively persistent (see fig. 5.11). However, current conditions must be assessed as drainage and irrigation can modify these physical controls, potentially removing alkali from the soil. The following paragraphs describe several potential ways to focus restoration.

Alkali Sink Scrub

A substantial portion of the historical extent of alkali wetlands (at least 22%) was occupied by alkali sink scrub. Alkali sink scrub was once an extensive habitat acrossk, alkali lands in the San Joaquin Valley and beyond through Southern

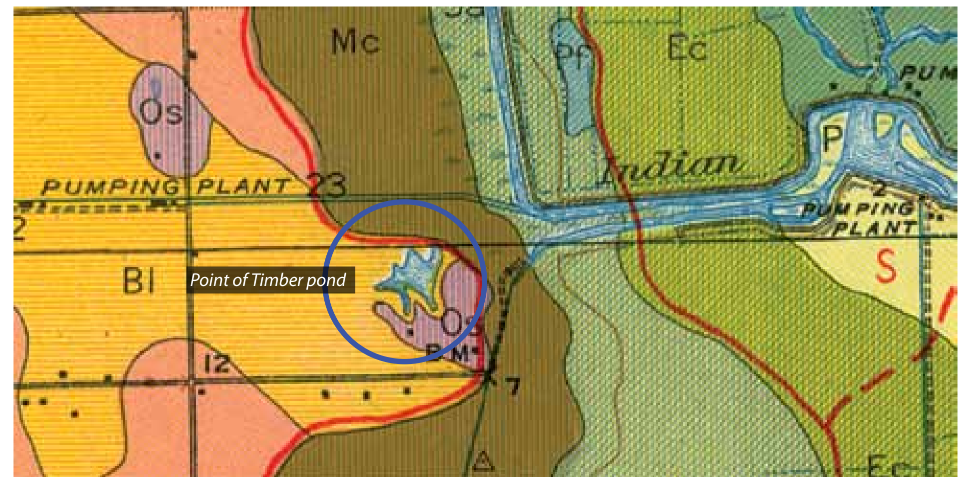


Figure 5.24. Historical representations of "Point of Timber" pond. These images consistently show the pond near the border of alkali habitats and tidal marshland. Note the patch of Oakley Sand (Os) on the soil survey southeast of the pond, which likely supported interior dune habitats. Note also the tidal marsh to the north and east depicted on both maps and visible in the photograph as a dark patch. The pond was located below the 5-foot contour, within range of extreme tides. (Counterclockwise from top left: USGS 1913 (Woodward Island); Carpenter and Cosby 1933; Russell ca. 1925, courtesy of State Lands Commission)

California (Freas and Murphy 1988, Jones & Stokes 1989). It provides habitat for a range of HCP species of concern such as San Joaquin spearscale, recurved larkspur, and brittlescale. Remnants of the large swath of sink scrub that extended along the eastern edge of the county still could provide opportunities for a range of potential restoration sites.

Restoration of Alkali Habitat Complexes

The historical landscape provides a template for considering the restoration of habitat complexes, which are combinations of associated habitat types. Such complexes often have the potential to support a wide range of species within a relatively small area. In the Byron area, alkali wetlands historically occurred in complexes of alkali meadows, flats, marshes, sink scrub, and vernal pools. Decades of human use have resulted in a number of modifications, including intensive cultivation and irrigation, adjacent development, and constructed ponds. Further assessment would be required to assess restoration potential. However, those remnants that remain give this area an unusually high potential for the establishment of a contiguous, functional wetland mosaic.

Restoration of Tidal Marsh–Alkali Wetland Mosaic

Similarly, the historical land cover map demonstrates that alkali habitats formed a broad transition to the tidal marshlands of the Delta along much of the eastern shoreline. This transitional zone was a mosaic of alkali meadow, alkali sink scrub, alkali flats, and alkali marsh integrated with high elevation tidal marsh habitats. There is potential for restoring some of this transitional zone east of Byron. This type of wetland mosaic would provide an array of habitat functions as well as critically important room for tidal marsh transgression in response to sea level rise, and, potentially, links between tidal, lowland, and upland habitats.

Wet Meadows and Discontinuous Creeks

Drainage and development have been important factors in the decrease in wet meadow area. Today streams draining north from the foothills have been channelized and run directly to the San Joaquin River; historically, they were largely discontinuous, spreading to flood seasonal wetlands (see Chapter 4). One of the reasons to channelize these drainages was likely prevent the formation of these seasonal wetlands along the tidal marsh by controlling the seasonal flood flows.

Historically, the northern edge of ECCC between Clyde and Antioch contained over 3,520 acres of wet meadow. While the historical soil survey describes that "the soil is boggy" underneath these meadows (Carpenter and Cosby 1939), in 1977 the soils were considered "moderately well drained" and "prime farmland if irrigated" (USDA 1977) and today they are almost entirely urban.

Stock Ponds and Perennial Wetlands

The construction of numerous stock ponds through the montane and foothill regions of ECCC has dramatically changed the hydrology and water supply system of the region. Stock ponds appeared in large numbers within the last 70 years; in 1939, we find evidence for fewer than 10% of the 405 ponds mapped by the HCP.

Stock ponds are both artificial features and potentially important habitats for native species of concern (Crifasi 2005). They alter local hydrology through water diversions and stream dams. These ponds also provide open water habitat and may reduce downstream flow. In ECCC they have led to a large increase in open water habitat. (See further discussion on p.43.)

ECCC historically contained perennial wetlands totaling at least 140 acres, including alkali marsh, valley freshwater marsh, perennial ponds, and seeps. By comparison, ponds alone measure 165 acres in the contemporary landscape, with an additional 1,800 acres of reservoirs and other large open water bodies. These numbers demonstrate the large increase in area of perennial open-water wetland habitats.

Some of the contemporary open water features occupy former natural wetlands (fig. 5.25, see fig. 5.19). Farmers and engineers often take advantage of semi-enclosed valleys that naturally retain water, creating levees or berms to increase the amount and persistence of surface water. For example Lake Alhambra occupies historical tidal marsh, and the Antioch Municipal Reservoir sits on the site of White Oak Springs. Both occupy natural low points.

Artificial ponds, especially stock ponds, currently provide some of the most important habitat for red-legged frog; however, they often also support predatory non-native fish and bullfrogs (Alvarez et al. 2004, Fellers and Kleeman 2007). Bullfrogs in particular pose a threat to red-legged frogs, such that the Contra Costa Water District created a program to eradicate bullfrogs. At sites where the conservation of red-legged frog is a priority and historical wetlands preceded artificial ponds, it might be considered whether benefits could be achieved by reverting to the natural wetland hydrology. Red-legged frogs have an advantage if wetland ponds persist long enough into the dry season to support red-legged frog reproduction while drying early enough to limit bullfrogs (Cook and Jennings 2007).

Historical Red-Legged Frog Habitat

Today, red-legged frogs are highly dependent on man-made water features such as stock ponds for breeding sites (Jones & Stokes 2006, Fellers and Kleeman 2007; fig. 5.26). The presence of red-legged frogs dating back to at least 1899 in ECCC (before the creation of these stock ponds) means that historically they relied on different habitats (Jennings and Hayes 1985). Through this study we were able to identify several potential natural historical red-legged frog habitats.

Although historical wetland extent was less than that found today, ECCC did contain significant seasonal and perennial wetlands (see discussion above). The springs, scattered valley freshwater marsh, and relatively large areas of alkali and wet meadow would all have provided potential breeding sites for red-legged frogs (Jones & Stokes 2006). Vernal pools within alkali meadows in particular may have provided key habitat.

Additional habitat would have been available along perennial streams. Kirker, upper Marsh, Kellogg, and Brushy creeks all had recorded pools and summer water in the late 1800s (see Chapter 4), which would have provided red-legged frog habitat. Perennial pools still persist along some reaches of these creeks (Bell pers. comm.).

Finally, red-legged frogs may have used habitat within the freshwater tidal marsh. Concurrent research in the Sacramento-San Joaquin Delta suggests that historically tidal marshes contained many open water pools or ponds, supporting native fish, yellow pond lily, and, likely, red-legged frog. The Pittsburg-Antioch lagoons and tidal ponds and sloughs in ECCC may have also provided important habitat. Red-legged frogs may have migrated to stock ponds in part because other breeding habitats such as vernal pools, streams, and seasonal wetlands have been drained or modified. Strategic restoration of some of these kinds of habitats may provide additional values as part of a "portfolio" of red-legged frog support functions.

Figure 5.25. Perennial alkali pond. This large pond, encircled by a crust of salt, is located at Vaquero Farms North, near Vasco Road and Byron. This pond occupies an area that was historically part of a swath of alkali meadow. (Photo by Abigail Fateman, CCC)

Figure 5.26. Red-legged frog. (Photo by Scott Hein, www.heinphoto.com)

Wetland Habitats

SUMMARY OF FINDINGS

1. **Historically, non-tidal wetland habitats covered an estimated 13,200 acres,** or 7% of the study area. Wetlands were concentrated in the lowlands along the northern and eastern edges of ECCC, in areas that are largely developed now.
2. **Fresh to brackish tidal wetlands covered over 22,000 acres,** or 12% of the study area . We mapped over 22,000 acres within our study area boundary, but more could be included by extending east to the County boundary. Over two-thirds of this area has been converted to agricultural land today, particularly on the eastern edge of ECCC, within the Delta.
3. **Over 98% of all non-tidal wetlands were seasonal wetlands**, which were wet for only part of the year. Seasonal wetlands included wet meadows, alkali meadows, alkali sink scrub, alkali flats, and seasonal ponds. Perennial marshes and open water wetlands were relatively rare historically and covered only a very small area.
4. **Alkali wetlands, both seasonal and perennial, formed a large, almost continuous swath along the eastern edge of ECCC,** measuring over 8,800 acres in extent. Roughly 30% of the historical alkali habitats remain.
5. **Seasonal wet meadows covered approximately 4,300 acres, mostly along the northern shore of ECCC.** These wetlands occupied clay soils and captured much of the water spreading from discontinuous streams flowing towards the tidal marsh.
6. **A series of brackish tidal lagoons was found along the Antioch-Pittsburg shoreline.** These tidal ponds embedded within the shoreline provided persistent open water habitats, and would have connected with the tidelands only during extreme high water.
7. **Wetlands were generally part of larger habitat complexes.** Alkali flats, alkali marshes, and alkali meadows formed in complex arrays, with the more saturated alkali marshes and flats surrounded by more seasonal alkali meadows. Freshwater ponds, marshes, and seasonal wetlands were similarly arranged along saturation gradients.
8. **ECCC contained extensive complexes of alkali wetlands, including vernal pool complexes.** Vernal pool fairy shrimp, closely associated with vernal pools, were recorded within vernal pools in alkali meadows and alkali flats. Alkali sink scrub, once common through much of the central valley, and historically covered 2,000 acres in ECCC.
9. **Most seasonal wetlands have been drained and replaced with urban/agricultural development.** Within the HCP, 3,290 acres of non-tidal marshes, seasonal wetlands, and alkali habitats remain, equivalent to only 25% of the historical wetland extent.
10. **There has been a dramatic increase in the area of open-water wetlands.** Open-water perennial wetlands (such as stock ponds and reservoirs) cover 2,371 acres today, compared to 135 acres historically. While stock ponds, most of which have been created since 1939, have resulted in the addition of many small, dispersed wetlands, most of the increase in area is due to the creation of a few large reservoirs.
11. **Some artificial wetlands have been created on top of historical wetlands.** Examples of this include Lake Alhambra and the Antioch Municipal Reservoir.

MANAGEMENT IMPLICATIONS AND NEXT STEPS

1. **The removal of seasonal wetlands has a continuing effect on local hydrology.** Historically, seasonal wetlands acted as temporary water reservoirs, absorbing peak flow and functioning as part of the water transport system. The legacy of this conversion likely includes greater peak flows and erosion.
2. **Seasonal and alkali wetlands have been disproportionately lost.** While some wetland types are over-represented in relation to historical distribution, others have been depleted and should be the object of restoration efforts.
3. **Historical distribution of wetlands provides a starting point for identifying suitable locations for restoration.** For example, many areas that were historically alkali wetlands retain alkaline and clay soils.
4. **The once-extensive tidal marshes have been largely lost and remnants will be threatened by accelerated sea level rise.** To support the persistence of tidal marshes in the future, priority should be given to creating space for tidal marshes to migrate inland in the face of climate change. In contrast to much of the margin of the Estuary, in ECCC some adjacent, low-gradient, less intensively developed upland areas provide potential opportunities to coordinate with willing landowners to allow this migration. Identifying and protecting these areas will be critical to the future of ECCC's marshes.
5. **In concert with Delta restoration there may be the potential for the re-establishment of a transition zone** between freshwater tidal marshes, alkali wetlands, and upland habitats in ECCC. This would represent a rare opportunity to restore a once significant landscape mosaic.
6. **Red-legged frogs that historically relied on more seasonal wetlands and dispersed perennial wetlands now rely increasingly on artificial stock ponds.** The hydroperiod of natural wetlands (many of which would dry out in the late summer) may be less sensitive to bullfrog invasion.
7. **Rare alkali habitat types, including alkali sink scrub and vernal pool complex, represent a significant regional restoration opportunity.** Some restoration has recently been accomplished by the HCP, but additional opportunities remain. Protecting and restoring these habitats has the potential to support a number of rare species covered in the HCP, such as brittlescale, San Joaquin spearscale, fairy shrimp, California tiger salamander, and adobe navarretia.
8. Res**toration should consider the restoration of habitat complexes along a gradient of saturation.** This historical habitat model can help managers create more varied wetland systems to support the diverse life-history needs of native species.

Figure 5.27. Alkali vernal pool. Concentric circles of vernal pool vegetation, including godlfields (*Lasthenia* spp.), are visible around the edge of this vernal pool near the Byron airport. (Photo by Abigail Fateman, CCC)

CHAPTER 6
DRYLAND HABITATS

September 17…After breakfast I walked with Dr. Marsh to the summit of a conical hill, about a mile distant from his house, from which the view of the plain on the north, south, and east, and the more broken and mountainous country on the west, is very extensive and highly picturesque. The hills and the plain are ornamented with the evergreen oak, sometimes in clumps or groves, at others standing solitary. On the summits, and in the gorges of the mountains, the cedar, pine, and fir, display their tall, symmetrical shapes.

-Edwin Bryant 1848

DRYLAND HABITATS

Woodland, savanna, chaparral, dune, and grassland communities together comprise the dryland vegetation of East Contra Costa County (ECCC; fig. 6.1). These communities provide a wide array of ecological functions and support many species of special concern. Among these, the San Joaquin kit fox (*Vulpes macrotus mutica*) and the Western burrowing owl (*Athene cunicularia hypugea*) are particularly associated with open grassland or savanna communities. Chaparral provides essential habitat for HCP species such as the Alameda whipsnake (*Masticophis lateralis euryxanthus*) and numerous rare plants such as Mount Diablo manzanita (*Arctostaphylos auriculata*). The Silvery legless lizard (*Anniella pulchra pulchra*) is supported by chaparral, savanna, dune habitats, and woodland communities with suitably sandy soils. While these communities may not be the primary habitat for wetland-associated species, many such species—including the Western pond turtle (*Clemmys marmorata*), the California tiger salamander (*Ambystome californiense*), and the California red-legged frog (*Rana aurora draytonii*)—depend on the dryland communities for movement or foraging.

During the development of the HCP, questions arose concerning historical changes in the dryland habitats supporting these species. These changes include the potential expansion of woody vegetation during historical times, which could have affected kit fox through reduced extent and changes in patch size of open grassland. Conversely, reduction of dune habitats may have negatively affected the silvery legless lizard. Loss of habitat connectivity due to development may negatively impact a host of native species. Understanding these changes and their implications can provide a stronger basis for effective management strategies.

Vegetation patterns in ECCC generally reflect physical controls such as slope, aspect, soil depth (Bowerman 1944 , Holstein 2000), moisture gradients (Griffin 1973), and disturbance regimes (Matsuda 1986; fig. 6.2). Many such physical factors interact to produce a landscape that is both spatially complex at the local level and

Figure 6.1. Views of dryland habitats: montane, foothill, and plain. A) North Peak, taken from the summit of Mount Diablo. B) Russell aerial photo, "one mile north of Brentwood," looking west across former grasslands and savanna, converted to agriculture by the 1920s. C) Clayton Valley , ca. 1913, with oaks (likely blue or valley oak) still standing in cultivated grain fields. (A: Storer 1912, courtesy of MVZ; B: Russell ca. 1925, courtesy State Lands Commission; C: Unknown ca. 1913, courtesy of the Clayton Historical Society)

generally presents discernable patterns at the larger scale. As ECCC lies within the rain shadow of Mount Diablo, much of the native vegetation reflects that of semiarid regions (Carpenter and Cosby 1939). Mount Diablo and ECCC comprise a unique region where ecological zones overlap and some species are found at the very northern-most limit of their range while other species occur at their southern-most limit (Bowerman 1944).

Many of the blue oak and valley oak woodland and savanna systems existing in California today are degraded and continue to degrade due to a variety of factors including persistently low oak recruitment (of particular concern with blue oaks) and declining tree densities, disease, mammalian consumption, invasive exotic species, and altered fire regimes (Bolsinger 1988, Kelly et al. 2005, Plieninger 2006, Tyler et al. 2006, Acacio et al. 2007, Zavaleta et al. 2007, Davis et al. 2011). These trends have raised concerns about the resiliency of these ecosystems to stressors such as climate change and further habitat fragmentation (Brown and Davis 1991, Davis et al. 2000, Sork et al. 2002, Mahall et al. 2005).

Due to the ecological and cultural significance of dryland habitats, conservation and restoration efforts are underway in many locations. A historical perspective can help ground these efforts to make restoration effective and sustainable. Historical ecology can provide a broader landscape perspective of the relative distribution and abundance of target habitats, and an understanding of variability under locally specific conditions. As with riverine and wetland systems, substantial research on terrestrial ecosystems in recent years has shown that conservation efforts can be misguided without accurate historical information, resulting in unsustainable or unprecedented restoration targets (e.g., Hamilton 1997, Foster and Motzkin 2003).

In this chapter, we discuss our understanding of the distribution, stand density, species composition, and other characteristics of the woodlands, savannas, chaparral, dune habitats, and grasslands in ECCC prior to significant Euro-American modification. We also address possible explanations for regional and local changes in these habitats during historical times. We describe methods and results, and discuss our findings within the context of regional studies on vegetation change. Specifically, we discuss the relative abundance of woodlands, savannas, chaparral, dune habitats, and grassland in relation to landscape position and other physical factors.

METHODS

Our understanding of native dryland habitats relies on a broad but heterogeneous set of historical data sources, each with their own social context and level of accuracy and uncertainty. Sources used to map dryland habitats include Wieslander Vegetation Type Maps (VTM; Wieslander 1935a), historical aerial photography (USDA 1939), mid-1800s General Land Office (GLO) survey data, explorer and traveler accounts, Mexican land grant maps and associated text, other early cartographic sources, and landscape photography (table 6.1).

Figure 6.2. Blue oak at Chaparral Spring. A mosaic of chaparral, grassland, and oaks along a trail in the newly acquired Chaparral Spring property east of Clayton, illustrating the rich habitat complexity in the upper elevations of East Contra Costa County. (photo August 19, 2006 by Scott Hein, www.heinphoto.com)

Table 6.1. Key data sources used to map dryland habitats. General data sources are listed with their associated uses in the mapping process, the era from which the source originates, its spatial coverage, and its accuracy. All sources also contributed to the assignment of habitat types.

Data Sources	Use of data	Era	Spatial coverage	Spatial accuracy
Narrative accounts	Corroborate relative density and location	1770s	Limited areas	Usually general
Maps	Refine habitat boundaries	1830s-1910s	Individual maps cover many parts of study area	Depends on source
GLO bearing tree data	Estimate point stand density, refine habitat boundaries	1850s-1870s	Distributed point data	High
GLO field notes	Corroborate relative density, refine habitat boundaries	1850s-1870s	Point data distributed across study area	High
Landscape photography	Corroborate relative density	1880s	Limited areas	Depends on source
Soil surveys	Establish correlation with soil type and tree presence	1900s	Continuous for study area	High
Aerial photography	Refine habitat boundaries, estimate oak population, establish correlation with soil type and tree presence	1930s	Continuous for study area	High

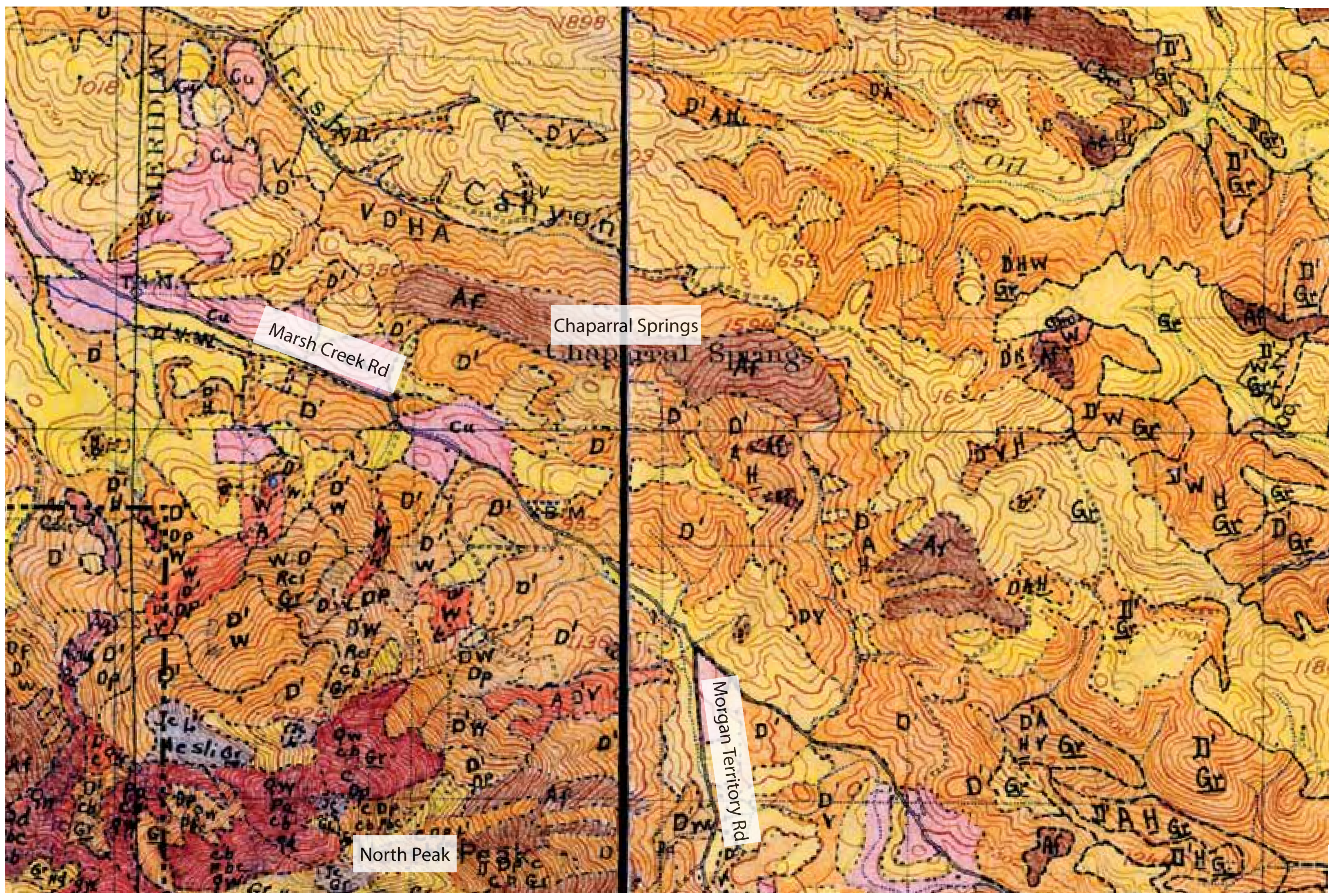


Figure 6.3. VTM map. This example area from a map produced on 15-minute USGS quads by Wieslander's Vegetation Type Mapping project shows the vegetation distribution in the vicinity of Chaparral Spring, just east of Clayton. The colors indicate vegetation types; the codes indicating dominant species, as determined by field work are listed for each vegetation polygon. Vegetation codes visible here include D' (*Quercus douglasii* - blue oak), Af (*Adenostoma fasciculatum* - chamise), and Cu (cultivated). (Wieslander et al. 1933, courtesy of ICE, UC Davis)

In general, historical data fell into two distinct groups, divided by geomorphic units (see fig. 2.4). In the montane geomorphic unit (or region; >900 ft elevation) and most of the foothills (200-900 ft elevation), VTM data and historical aerial photography were available, but few pre-1930s sources were available. Conversely, in the plains region (<200 ft elevation), extensive 19th-century data were found, but VTM and early aerials were less useful because of the extent of modification by the 1930s. As a result, historical mapping of the upper elevations is more systematic but derived largely from later sources, while plains region data sources are more heterogeneous but earlier.

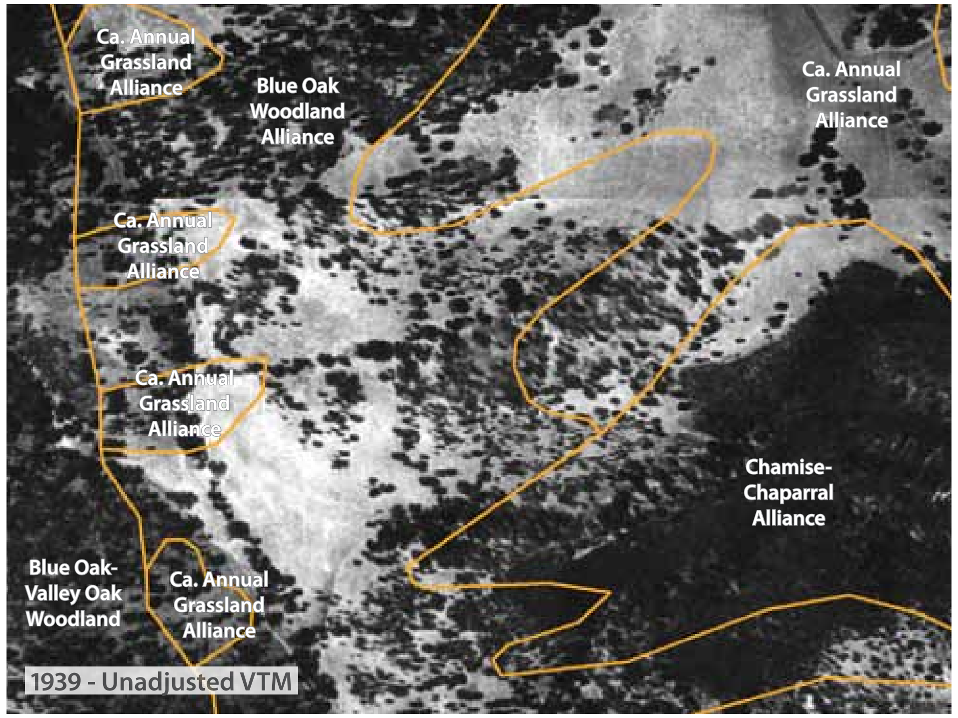
While most of our detailed mapping in the upper elevations relied upon 1930s data, some early sources, land use history, and contemporary literature discussing vegetation trends did allow us to refine our mapping and build confidence that the mapping generally represents overall extent and relative composition of ECCC vegetation prior to significant Euro-American modification, though substantial uncertainties exist at the local scale and in terms of vegetation density. Dominant anthropogenic drivers of change vary depending on location, and they include changes to fire frequency and grazing practices in the montane region, and urban and agricultural development in the lower plain. For most analysis, we used the geomorphic units derived from the HCP (Jones & Stokes 2006): montane, foothills, and plains. We maintained a minimum mapping unit of 5 acres to provide consistency when mapping from sources of different scales and to avoid overmapping.

Reconciling Wieslander Vegetation Type Mapping with Historical Aerial Photography

The earliest comprehensive effort to map California vegetation began in the 1930s, when Alfred Wieslander led the Vegetation Type Mapping (VTM) project for the U.S. Forest Service (Wieslander 1935a). The effort produced a set of vegetation maps, as well as plot data and maps, species inventories, and landscape photography, the protocols for which were documented in a carefully developed field manual (Wieslander et al. 1933). The vegetation type mapping was conducted in the field directly on 15-minute (1:62,500 scale) U.S. Geological Survey (USGS) quadrangles without the benefit of aerial photography. Vegetation was classified as either complex vegetation mosaics or as pure or mixed stands, with the dominant as well as subdominant species listed (fig. 6.3).

These data have proven to be a valuable resource for researchers attempting to understand vegetation patterns and change over the past century. Recently, researchers at UC Berkeley and UC Davis have digitized many of these records (Kelly and Allen-Diaz 2005, Thorne 2006). The information has been used in a number of studies including the statewide California Gap Analysis project (Davis et al. 1998) and a regional analysis examining vegetation change (Thorne 2006). However, few, if any, studies have compared the mapping to early aerial photography, which followed the VTM efforts by just a few years. As a result, there has been little assessment of their local-scale spatial accuracy and applicability to local ecological planning.

We acquired digital versions of the vegetation maps through Dr. Jim Thorne and the Information Center for the Environment (ICE) at UC Davis. These digital maps were created by georeferencing and then digitizing the original VTM maps (Morgan et al. 2007). Each polygon was attributed by the ICE group with Wildlife Habitat Relationships (WHR; Mayer and Laudenslayer 1988) and Manual of California Vegetation (MCV; Sawyer and Keeler-Wolf 1995) vegetation classifications, based on the dominant species listed by the VTM cartographers. Visual comparison to the contemporaneous aerial photography dataset made it clear that the VTM mapping scale was far coarser (e.g., generalized topography creating generalized vegetation polygons) than the mapping scale possible using aerial photography. This scale difference is expected given that VTM mapping



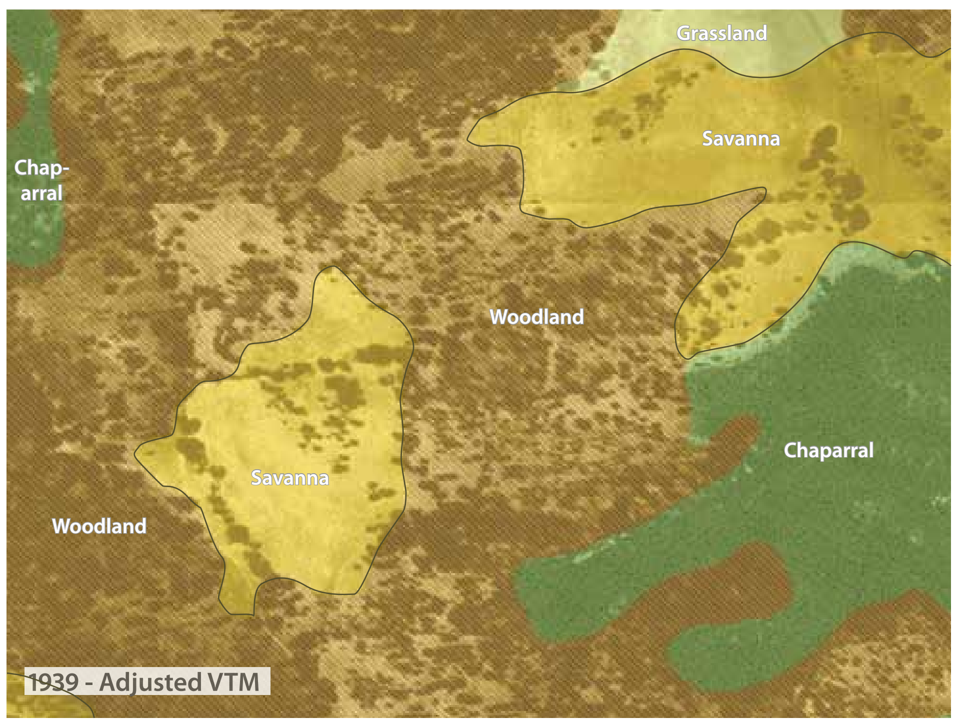


Figure 6.4. Adjusting VTM polygons. Original Wieslander VTM polygon boundaries (shown as orange lines with MCV alliance labels in the upper image) follow the general pattern of vegetation type visible in aerial photography, but are clearly distorted in part due to the more general USGS topographic quads and field methods used by the VTM. The blue oak woodland and chaparral boundaries in particular do not follow those clearly visible and mappable in the historical aerial photography. Shown below are adjusted polygons, classified by the general habitat type used in our mapping. These polygons also include attribution of the more detailed species community information offered by the VTM mapping. For example, the lower right chaparral polygon in the bottom image contains the VTM attribute of Chamise-Chaparral Alliance, based on the VTM polygon it is coincident with Both versions are shown against 1939 photography. (USDA 1939, courtesy Contra Costa County and Earth Sciences & Map Library, UC Berkeley)

was performed by hand on USGS maps at a scale of 1:62,500. We concluded that the potential for improving the mapped vegetation boundaries using the historical aerial photography was high and would enhance detection of areas of change (fig. 6.4).

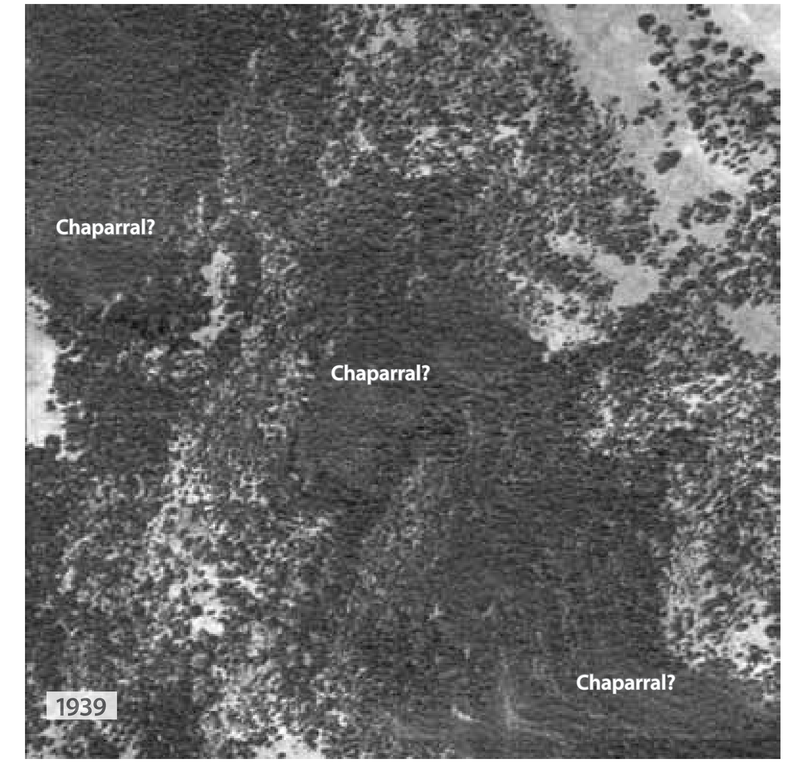
We therefore developed methods to create a more spatially detailed habitat map, while retaining the information of the attribute-rich field-based VTM maps. Through initial overlay comparisons with the HCP vegetation mapping (Jones & Stokes 2006) we noted significant similarity in vegetation patterns. To avoid redundant work and overestimates of change, we used the HCP mapping as the starting point. In the parts of the study area that were not extensively developed by the 1930s (primarily in the foothills and montane region), we developed the historical habitat map by adjusting polygon boundaries where appropriate and filling in the attributes using VTM data.

Four primary habitat classes were defined to correspond with the Jones & Stokes (2006) classification: chaparral, woodland (>10% tree cover), savanna (5-10% tree cover), and grassland (<5% tree cover; Barbour et al. 2007, California Fish and Game Code §1361). For the generation of comparable datasets, we matched the patterns mapped by Jones & Stokes (2006), particularly in the distinction between savanna and woodland. For both datasets, the 10% cutoff is soft. We usually found boundaries between denser (woodlands) and sparser (savannas) areas relatively easy to detect as most woodlands were quite dense. Rock outcrops mapped by Jones & Stokes (2006) were left unchanged. The chaparral class encompasses both chaparral and sage scrub communities due to the difficulty distinguishing between these types in the historical aerial photography. Similarly, the woodland class includes both oak woodland and upper montane forest types. Although these types were not distinguished at the primary habitat type level due to limitations in detecting vegetation differences from historical aerial photography (Jones & Stokes 2006), the VTM attributes provide some information to make such distinctions.

We used habitat boundaries visible in the historical aerial photography to adjust polygon boundaries and assign habitat types that largely reflect 1939 conditions. Mapping was performed at a scale of 1:5,000 with a 5 acre minimum mapping unit. Polygon boundaries were adjusted if the distance of change exceeded 150 ft (a distance greater than the uncertainty associated with digitizing sources).

Some boundaries were difficult to adjust due to challenges in detecting texture differences in black and white photography (e.g., chaparral boundaries, fig. 6.5). To determine native habitat type assignment for the upland areas with clear human alteration, such as farming or clear-cutting, we extrapolated from available data to assign a native habitat type. This included using textual descriptions of the area or, where no additional data existed, basing attribution on adjacent vegetation type.

To take advantage of the rich species data included in the VTM maps, we attributed the mapped polygons with VTM species composition information using a spatial join. We also divided habitat polygons (e.g., woodland) based on species composition boundaries indicated on the VTM map. That is, the habitat type boundaries (e.g., woodland) were digitized based on vegetation boundaries evident in the aerial photography, but subsequent refining within those classes included the use of less accurate VTM polygon boundaries, which often followed topographic boundaries. This process resulted in a one-to-one relationship between the VTM attributes and the 1939 historical habitat polygons. The purpose was to create a historical map generated at a scale that would facilitate change detection using the contemporary dataset, while also providing additional detail on the habitat species composition available from the VTM dataset.



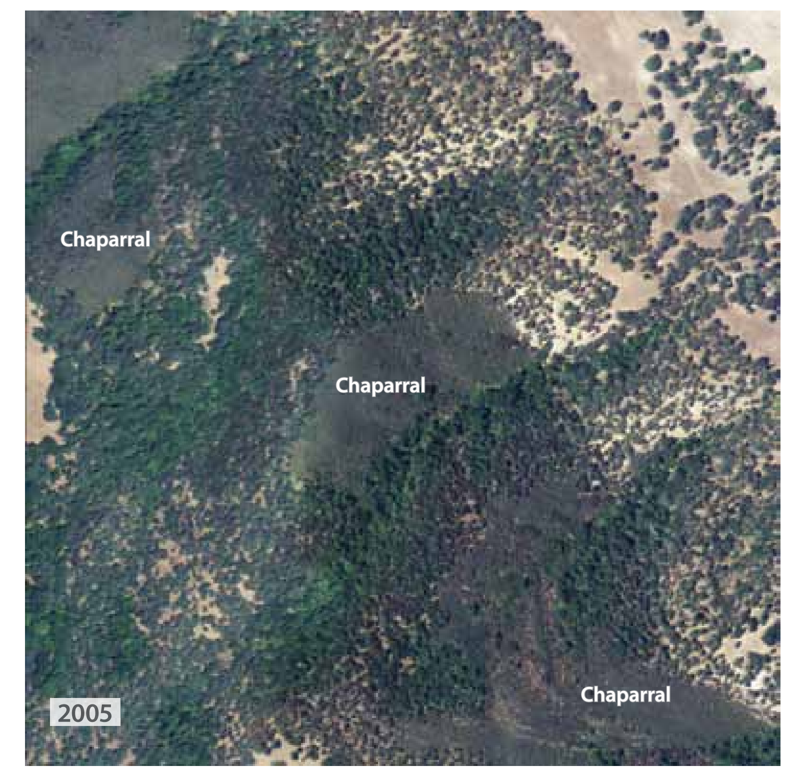


Figure 6.5. The challenge of detecting chaparral boundary in historical aerials for mapping purposes. These two aerial photos, taken in 1939 (top) and 2005 (bottom), illustrate the difficulty in determining whether any change in vegetation type boundaries is visible between these two time periods represented. In such cases as these where no clear boundary shifts are visible or where texture differences are inconclusive, no change was mapped. (Top: USDA 1939, courtesy of Contra Costa County and Earth Sciences & Map Library, UC Berkeley; Bottom: USDA 2005, courtesy of NAIP)

Summarizing General Land Office Survey Data

The General Land Office (GLO) Public Land Survey (PLS) field notes provide detailed descriptions of landscape and vegetation prior many of the extensive environmental changes that followed Euro-American contact (Buordo 1956). The GLO survey data have provided researchers throughout the U.S. with ecological data at a level of accuracy, consistency, and spatial extent rarely available from other sources of this era. The GLO survey progressed from Ohio to the West Coast after being initiated in 1785 by the Land Ordinance. The survey reached Contra Costa County in 1851 and continued surveying the area until 1875. The survey established townships of 36 mi^2 divided into square mile sections. The section and township corners ideally form a square grid across the landscape at a resolution as fine as the quarter-section. However, many areas in California, including parts of the study area, lack a complete network of inner township section lines as a result of private Mexican land grant holdings, as well as, in the case of this study, the Delta tidal marshes and some areas of exceptionally steep terrain on Mount Diablo (White 1991, Whipple et al. 2011).

The GLO field notes contain a wealth of information about local ecology and hydrology. This includes descriptions of overstory and understory composition, creek seasonality and channel geometry, and ponds and marshes. In addition, to establish section corners and quarter-section points (at the mile and one-half mile points), surveyors recorded the species, diameter, azimuth, and distance from the survey points for up to four "bearing" trees, ideally one tree per quadrant. If no trees were available within "convenient and suitable distances," surveyors were instructed to establish a mound and trench (White 1991). In addition to bearing trees, surveyors recorded the species and diameter of trees encountered in the path of survey lines ("line" trees).

We adapted methods developed by the Forest Landscape Ecology Lab at the University of Wisconsin-Madison to store, display, and analyze the GLO data within a GIS environment (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 the ability to place the survey points efficiently and accurately within a contemporary spatial coordinate system. The resulting database can be easily manipulated for subsequent analyses. These data have been used most often in reconstructions of historical forest structure and composition in the Midwest and Northwest but relatively rarely in California systems (Radeloff et al. 1999, Collins and Montgomery 2001, Bloom and Bahre 2005, Brown 2005, Whipple et al. 2011).

We performed quantitative analysis of the GLO bearing tree dataset to estimate tree density by calculating point density estimates. This information was used to compare across different regions of the study area and to estimate average tree densities. Various different methods have been used to estimate density based on GLO bearing tree data (Bouldin 2008). We used both the point-centered quarter method developed by Cottam and Curtis (1956) and the more robust Morisita (1957) formula (see appendix for details). We also evaluated the GLO tree dataset for diameter at breast height (dbh) distribution and species composition, which were summarized by geomorphic unit.

While these surveys were systematic and spatially comprehensive, researchers have noted the importance in understanding potential bias, such as preferences for tree species with easily marked bark, trees of particular size classes, or trees within particular angle quadrants (White 1983, Radeloff et al. 1999, Collins and Montgomery 2001, Kronenfeld and Wang 2007). Inconsistencies also exist depending on individual surveyors, and it should be kept in mind that although the surveys recorded valuable ecological data, their intended purpose was to sell land to settlers and timber, railroad, and mining interests. As an example of possible effects, an underestimation of tree density would result if some surveyors tended to select trees other than the closest trees. Although it was not possible to quantify the bias of this dataset, examination of the range of species and the size-class distribution suggests that one can draw meaningful comparisons from the dataset.

In addition, it is important to note that each survey represents conditions present at one particular point in time. However, while extreme events (such as flooding in 1862) may impact descriptions of temporally dynamic characteristics such as stream flow, the distribution of long-lived features such as oaks is unlikely to be affected by most short-term weather events.

Integrating Additional Data Sources

While VTM data and early aerial photography provided extensive information in the uplands, earlier historical sources were of paramount importance, particularly when mapping dryland features on the alluvial lowlands. The plains were already developed and under cultivation by the time of the Wieslander VTM project and the historical aerial photography, so these sources could be used only rarely for mapping historical vegetation in this part of the study area. Instead, we used primary historical sources that included GLO, narrative accounts, soils, and other historical maps. Most were earlier, though less spatially-detailed and comprehensive, than the VTM and historical aerials. We used a variety of methods to incorporate these additional data sources.

Qualitative use of GLO contributed to our mapping efforts as part of the GIS synthesis process. For example, where surveyors noted entering timber or brush or little tree cover, we used this to provide 19th century calibration of 1930s-era habitat boundaries. These data were especially useful in areas such as the plains region which were already heavily modified by the time of the VTM maps. The field notes also provided valuable, mid-19th century narrative accounts of the landscape, such as whether slopes were densely covered in brush or sparse timber.

To better understand soils as a factor contributing to tree location in the plains region, we used GIS and chi-square analysis to correlate canopy sized trees (> 15 m) digitized from the 1939 historical aerial photography with soil types (Neu et al. 1974, Mahall et al. 2005). Trees were digitized based upon their distinctive size, shape, and groupings (Brown 2002, Sork et al. 2002, Mahall et al. 2005). Our preliminary evaluation using digitized trees from historical aerials to determine soils associated with savannas or woodlands was fairly inconclusive. However, we did find that soils tending to have higher oak density matched areas supported by other sources. Other soil types with pronounced characteristics, such as the Oakley sands, do appear, through qualitative evaluation, to reflect different habitat types. Soil descriptions were useful as well: the 1939 soil survey identifies an area of Cayucos adobe clay southeast of Antioch as a type that supports "a few oak trees," where "intervening spaces are carpeted with grasses" (Carpenter and Cosby 1939). Such soil type distinctions were found to be especially useful in the plains region where topographic effects were not as significant in determining vegetation patterns. Although we were not able to establish oak-bearing soils with a certainty high enough to map oaks directly from the soils in the absence of other evidence, we were able to use these soils to refine oak polygon boundaries when other sources indicated oak presence.

In addition to soils and GLO survey notes, we found that historical maps, early photographs, and narrative accounts all provided valuable data. Usually several lines of corroborating evidence contributed to our understanding of historical dryland conditions. For example, to map the large stretch of oak savanna along the eastern edge of East Contra Costa, we relied heavily on GLO surveys, soils, and the 1853 Whitcher map (see p.7). We sketched the initial polygon directly from Whitcher's map and then compared this shape with the locations of GLO bearing trees, narrative data, and lithographs of the area. We found that this shape matched well with both these sources and the 1933 soil survey (Carpenter and Cosby 1933). Towards the mouth of Marsh Creek, Whitcher shows a gap in the oak cover that corresponds with a large patch of Sorrento clay. This clay soil would have been too wet to support oaks and suggests that Whitcher purposefully did not place oaks here. In this way, we were able to use the soils map to refine the oak savanna polygon. By using many sources as corroborating or conflicting evidence, we were able to map historical habitats with a much higher degree of confidence than would have been possible by using the individual sources in isolation. Each mapped polygon was assigned certainty levels of either high, medium, or low for three different characteristics: habitat type interpretation, feature size, and feature location (see p. 10). In general, features mapped from earlier and more spatially accurate sources tended to be assigned higher certainty levels.

To explore within-habitat class density shifts over the past 70 years and the nature of that change, we also developed a preliminary method of raster image analysis that would, for a given area, show the location as well as trajectory of change between woody vegetation cover (chaparral or trees) and no cover (grassland). This was done with binary classification of the images' pixel values as woody vegetation cover (dark) or no cover (light), the areas and locations of which could then be compared between the two years of aerial photography (Mast et al. 1997). For full discussion of this method, see appendix. Although visually many places appeared to have become denser through either tree growth or filling in of chaparral, this preliminary analysis produces relatively inconclusive results given uncertainties associated with determining appropriate pixel value breaks for comparison between the time periods and complications such as shading. A true analysis to test vegetation change hypotheses using remote sensing techniques was beyond the scope of the project. In addition, ideally an analysis such as this would be accompanied by on-the-ground field measurements of tree age classes to better understand apparent trends in tree density and tree size.

RESULTS

The historical landscape of ECCC included a wide range of plant communities (fig. 6.6). Some maintain significant expression in the contemporary landscape, while others do not. Dryland vegetation patterns reflected the topographic, elevational, and edaphic controls of the region. As it does today, chaparral generally dominated shallower soils, while grasslands or savannas occupied deeper soils on south slopes and woodlands occupied deeper soils on north-facing slopes (Holstein 2000, Ertter and Bowerman 2002). Oak savanna and grassland historically occupied large areas of the valley floor, merging into smaller, but more numerous patches of woodland and savanna that followed topographic boundaries in the foothills, with grassland occupying the more "exposed slopes" (Carpenter and Cosby 1939). These habitats transitioned into oak woodland and montane forest interspersed with patches of chaparral, savanna, and grassland in the upper elevations of Mount Diablo. Within the highest elevations of Mount Diablo, pine, juniper, scrub oaks and other chaparral species dominated, with relatively few areas of grass (Hilgard 1881), similar to today. (fig. 6.7, table 6.2)

Habitat complexity and relative patch size reflect the complexity of the physical characteristics. These relationships were noted by early observers, as in this description relating the distribution of vegetation on Mount Diablo to topography: "the hills and lower slopes of the mountains being dotted over with picturesque oaks; standing alone or gathered in clumps; while the ravines that furrowed their sides were filled with chaparral and innumerable flowering shrubs" (Degroot 1875). Another writer characterized the pattern in the upper elevations of Mount Diablo as follows: "to the very summit, wild oats and chaparral alternate. In the canons are oak and pine trees from fifty to one hundred feet in height; and on the more exposed portions there are low trees from twenty to thirty feet in height" (Olmstead 1962; fig. 6.8).

Loss of native habitats within the lower elevation regions of ECCC has been significant. Direct effects due to agricultural and urban development have had the most dramatic impact on the relative distribution and abundance of dryland habitats. These modifications have transformed the plains, making pre-modification patterns unrecognizable.

Changes are less pronounced, though potentially not insignificant, in the upper elevations. Some localized change is quite evident due to direct effects of clearing, while other changes are more subtle and may be attributed to multiple interacting long and short term indirect drivers of change (fig. 6.9). While some apparent changes as detected when comparing the historical and modern habitat mapping may be attributable to imagery interpretation and classification errors, overall distribution and extent of habitat types are apparently still largely controlled by topography and other physical factors. Available evidence suggests that the proportion and distribution of dryland habitats within the montane (>900 ft elevation) and foothill (200-900 ft elevation) regions of ECCC have remained largely consistent over the last 70 years and likely the last 150 years, at least within the resolution of available historical information and between the defined habitat types. It should be noted, however, that our mapped distribution may not include some woodland or savanna areas that were cleared or thinned prior to 1939, given the dependence upon 1930s-era data sources. For instance, historical and qualitative data do suggest several drivers of change that would have led to cutting of blue oaks in the foothill region early on. Some evidence suggests that the 1930s may have been a low point for woodland and savanna cover (Adams pers. comm.). Also important to consider is that changes within habitat types may be significant, such as the introduction of native grasses or the gradual loss of individual trees due to mortality and low recruitment. Overall, the effects of changing grazing and fire regimes appear to have caused few large-scale vegetation type changes, and shifts in vegetation boundaries are not large, though density shifts in both blue oak woodland and chaparral are detectable in some areas. Although a thorough evaluation of possible changes from the mid-1800s distribution in these regions due to more these more indirect factors is not possible at this time, we explore these likely losses qualitatively.

Figure 6.6. Dryland habitats. Dryland habitats include fields of poppies, buckeye and oak trees near Vasco Caves, a patchwork of woodlands , grassland, and chaparral on the hillsides, and grazed grassland. (Left and middle right photos by Scott Hein, www.heinphoto.com; Middle left photo by Ruth Askevold; Right photo by Abigail Fateman, CCC)

Table 6.2. Estimated total acres of natural dryland habitats. Total acreage includes some areas that were mapped outside of the HCP (dune habitats, in particular) and are not reflected in the contemporary numbers. The difference between historical and contemporary acreages reflects conversion to agriculture and urban land use. (Contemporary numbers from Jones & Stokes 2006)

Class	Habitat	Historical Acreage	Contemporary Acreage
Dryland	Grassland	97,000	58,409
	Woodland	25,300	24,198
	Oak savanna	17,000	5,894
	Chaparral	3,300	3,016
	Rock outcrops	120	142
	Interior dune habitats	8,500	
	Total	**151,230**	**91,659**

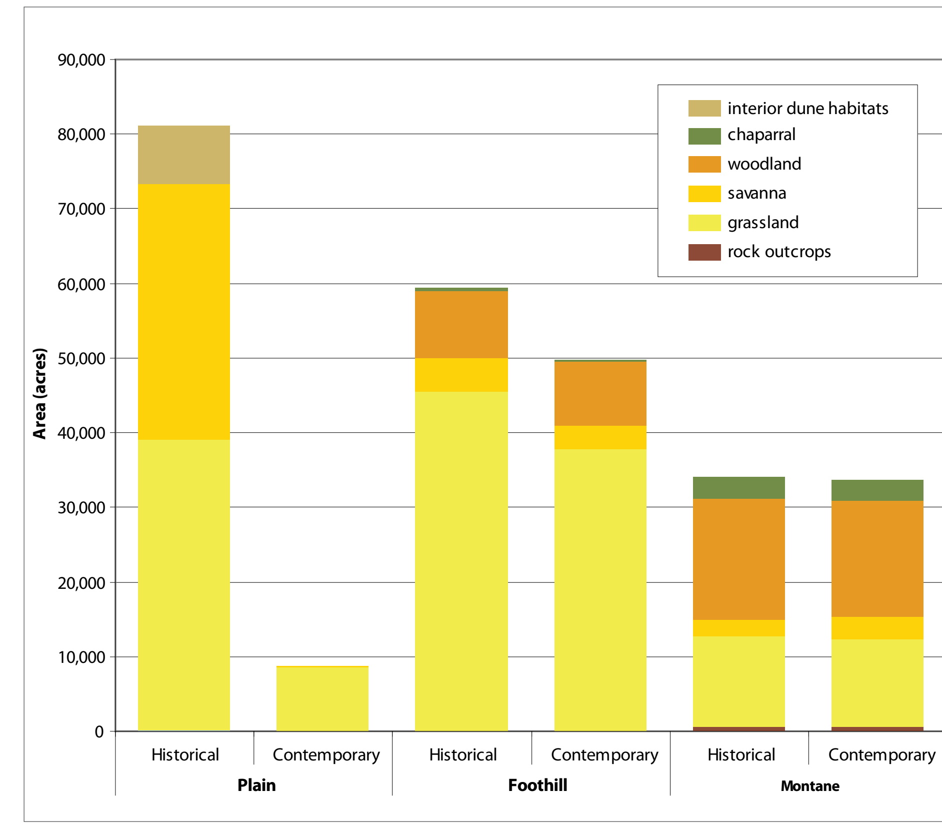
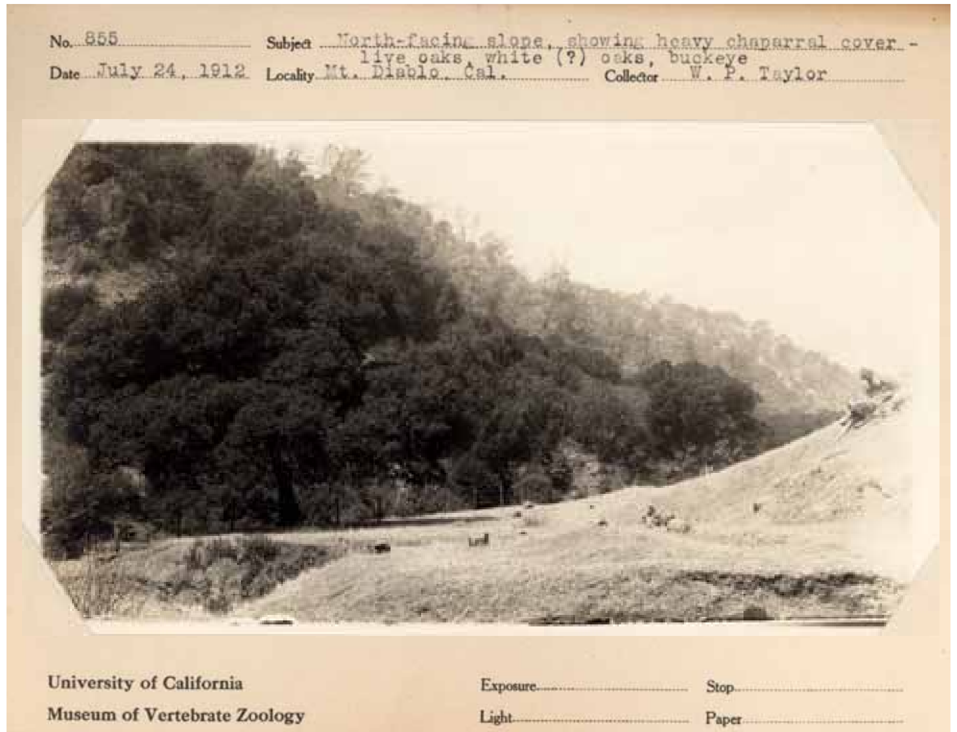


Figure 6.7 Historical and contemporary dryland habitats by geomorphic unit. (above) The greatest change in dryland habitat extent has occurred in the plains geomorphic unit. Virtually all plains region interior dune and savanna habitat has been developed or cultivated. The foothill region has also lost a significant amount of native dryland habitat cover, mostly attributable to loss of grassland to development and agriculture. The montane region has changed relatively little, though a noticable increase in savanna is likely due to a related decrease in woodland as a result of localized clearing. The plains region difference can be expected to be largely reflective of change since the mid-1800s, while the foothill and montane regions are more reflective of change since 1939. It should be noted, however, that due to uncertainties some apparent changes may be a result differences in mapping methods and aerial photo interpretation. This graph shows acreages for the six natural vegetation types (the two dune habitat types have been combined) and not the urban and other human-influenced land cover types, which explains the dramatic loss of total acres in the plains. Loss (or gain) in acreage for any particular habitat type may be due to a number of different factors.



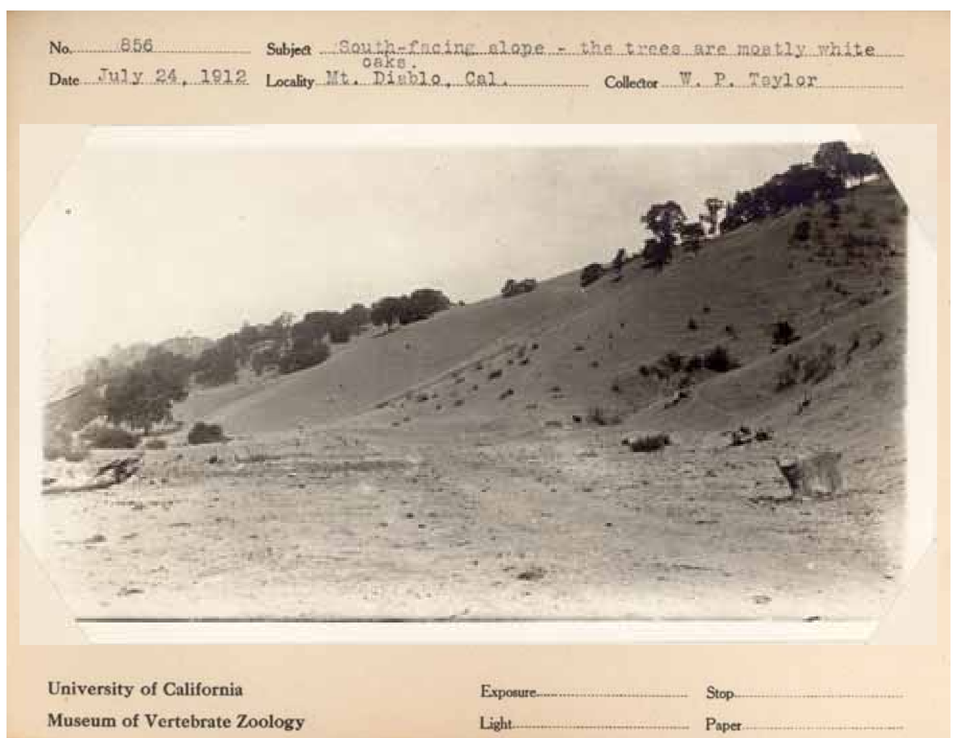


Figure 6.8. Differences in north and south-facing slopes. Note the contrast between the north-facing slope covered with live oaks and chaparral (top), and the relatively open and grassy south-facing slope (bottom). Exact location within the Mount Diablo foothills is unknown. (Taylor 1912b,c, courtesy of Museum of Vertebrate Zoology)

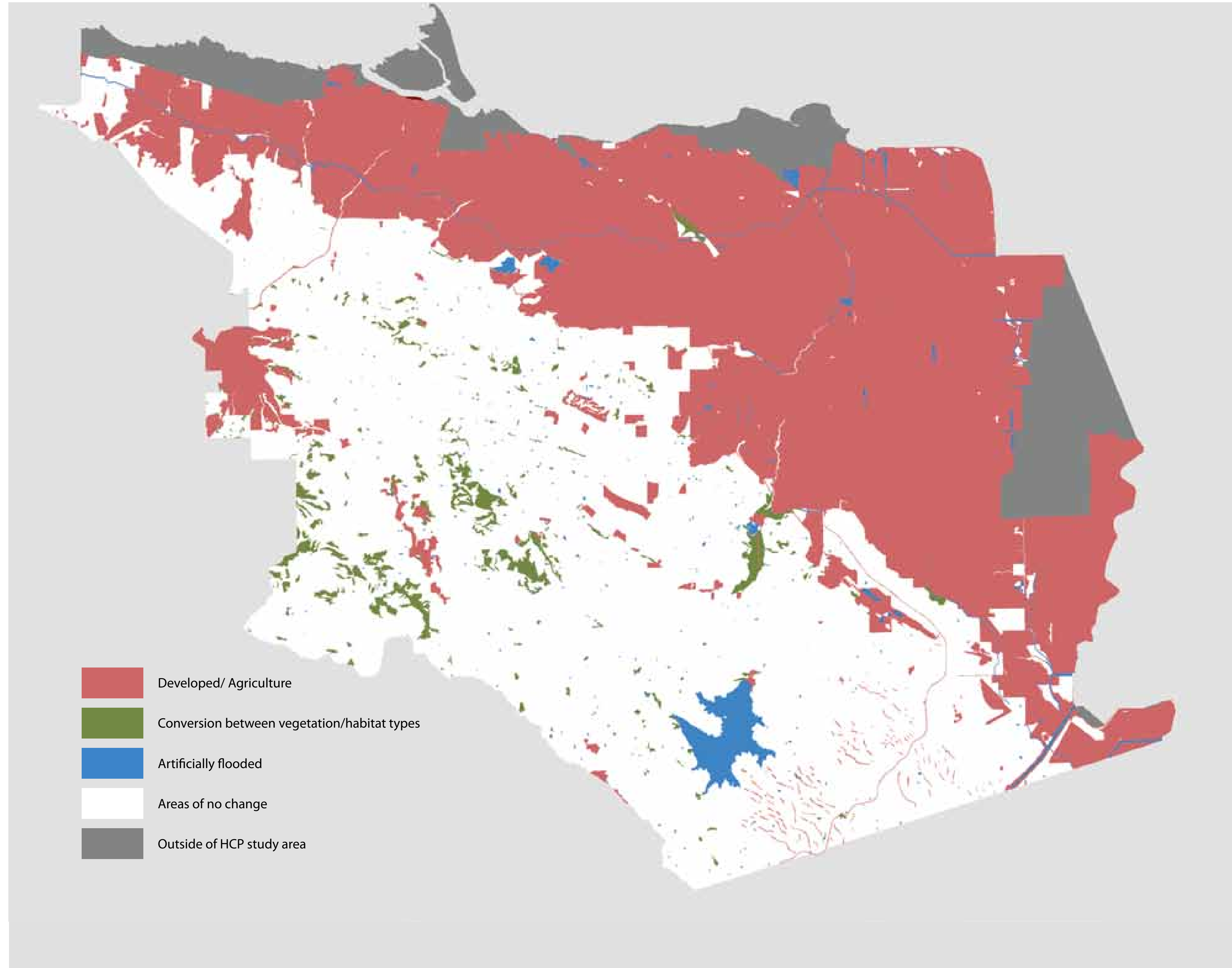


Figure 6.9. Selected areas of change within study area. A spatial comparison of historical and contemporary habitat mapping reveals particular areas that have undergone change. The reddish areas on the map show all historical habitats developed since historical times (e.g. urban and agricultural development). The green areas represent shifts between vegetation/habitat types (e.g., conversion of chaparral to grassland types) rather than alliance or association-level shifts (e.g., between types of oak woodland). This includes, for example, patches of woodland in 1937 that were thinned to savanna densities by 2005. This appears to have been the most common trend. However, this conversion also includes less extensive type conversions, such as expanding boundaries of chapparal into grassland. Some apparent conversion may also be a result of differing aerial imagery interpretation and classification methods between our and Jones & Stokes (2006) efforts. The blue areas have been largely artificially flooded (e.g., reservoirs, aqueducts). Many small features cannot be seen at this scale – this image captures change over areas larger than a few acres in size.

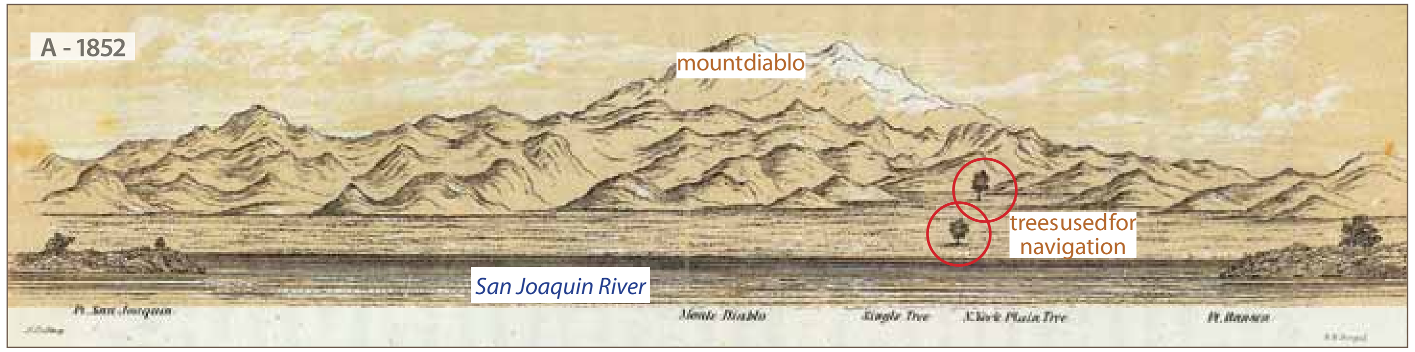
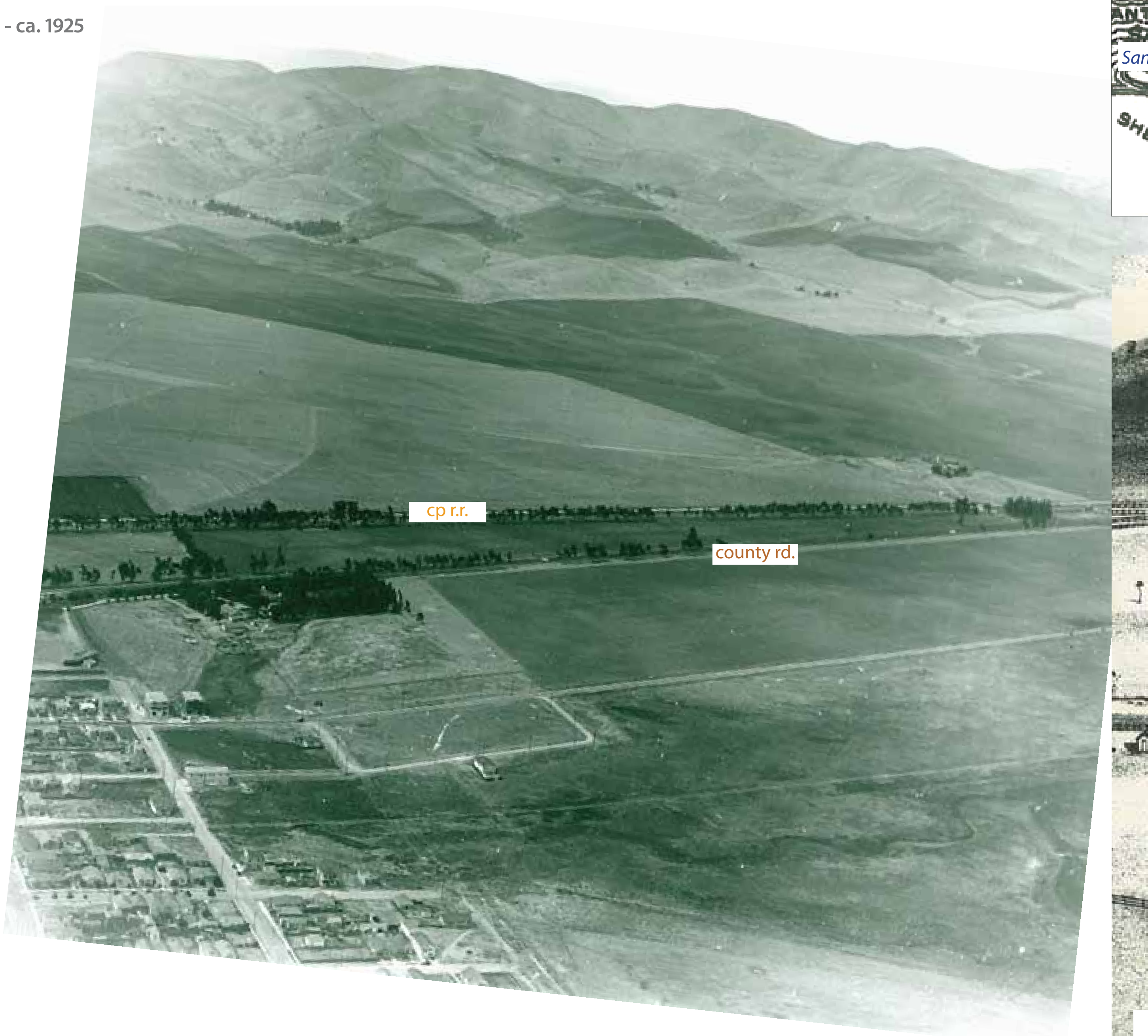
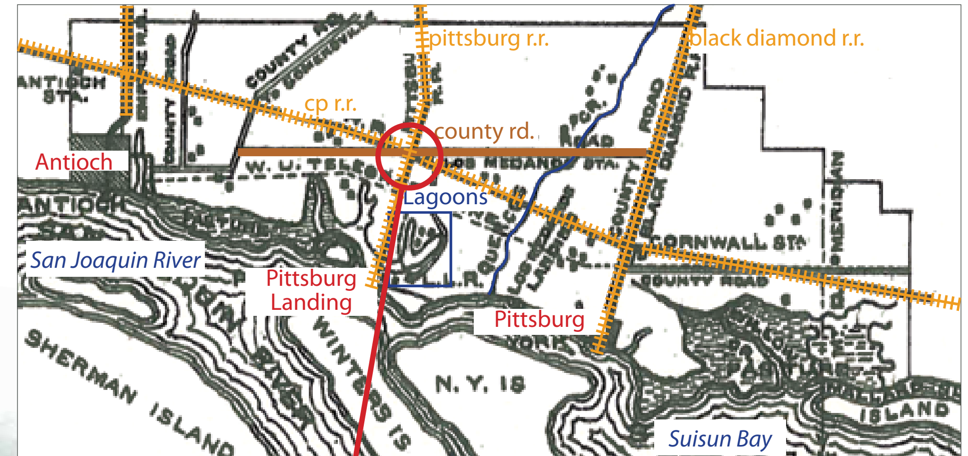


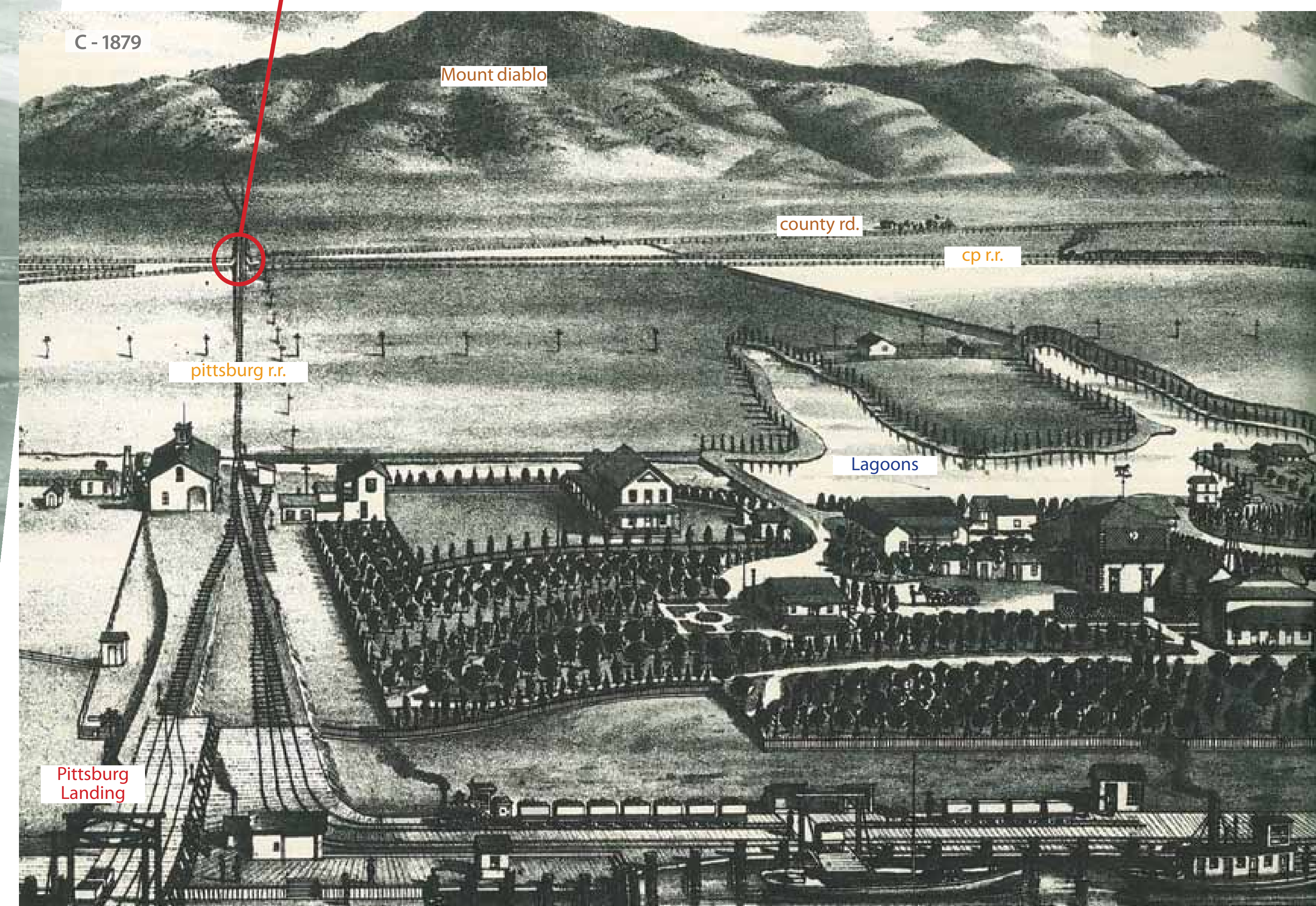
Figure 6.10. Three views of the treeless plain looking south from Pittsburg toward Mount Diablo. A) This image from Ringgold's 1852 charts of the San Francisco Bay shows distinctive and solitary trees, used for navigational purposes. Ringgold likely omitted foothill trees that were not relevant to navigation. B) Grasslands of the plain east of Pittsburg, shown in this image ca. 1925, lie directly to the east of Robinson's Landing, shown in image C). Some clearing may have occurred by this time. Note that the only visible trees occur along the railroad tracks in a planted formation and in the foothills. C) Robinson's Landing (near Pittsburg) and the planted grounds of Robinson's farm contrast with the treeless plain and scattered foothill trees. Note the intersecting county road and railroad lines shown on both images B and C. Although the drawings were intended for a specific purpose and may not have shown each individual tree, and the photograph was taken relatively late, after some clearing had certainly taken place, these images do give a sense for the generally treeless plain. (A: Culberg and Dougal 1852, courtesy of the David Rumsey Collection; B: Russell ca. 1925, courtesy of the State Lands Commission; C: Smith and Elliott 1879)

B - ca. 1925



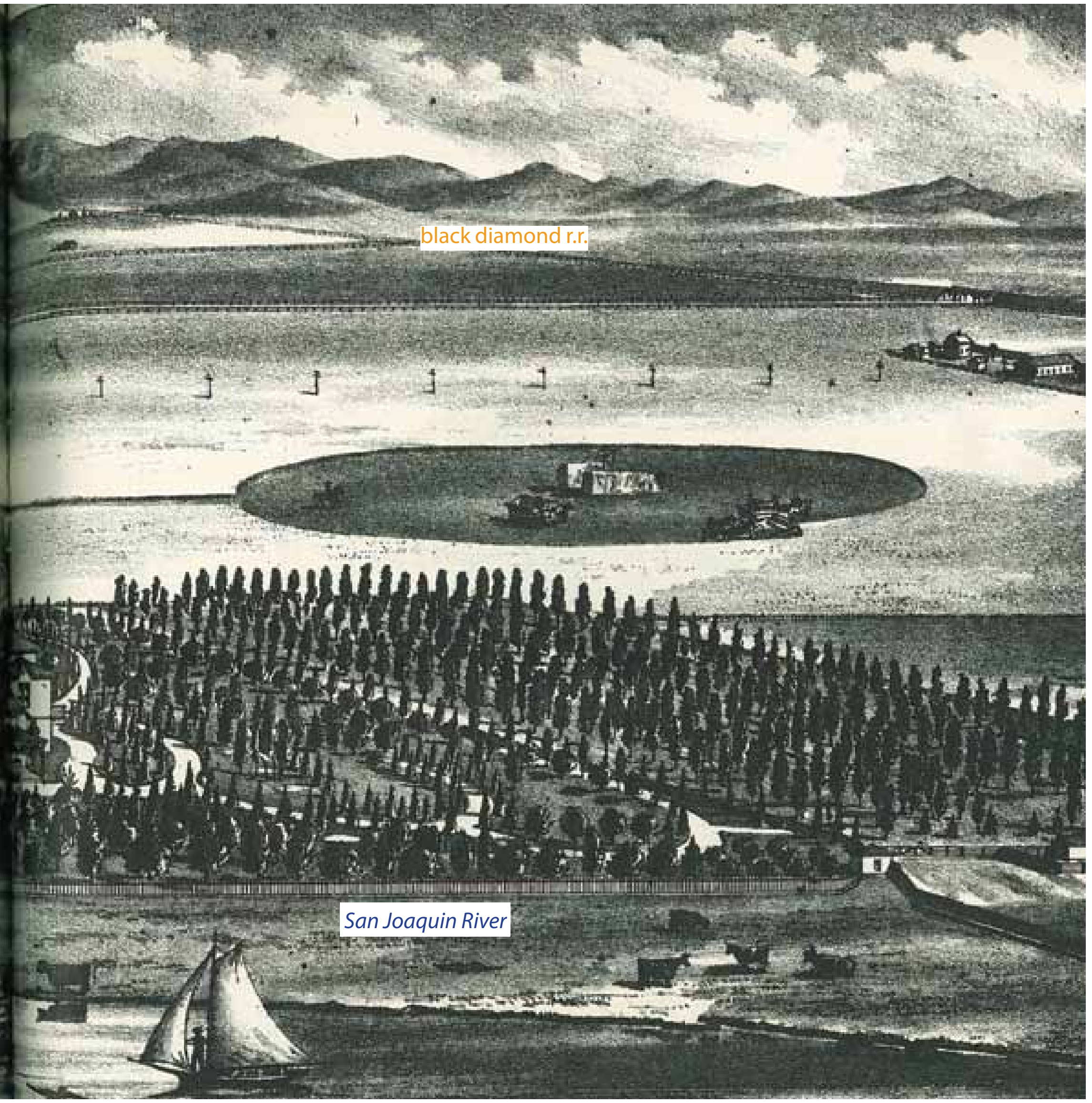


C - 1879



Grassland

Grassland and annual forbland (hereafter, grassland) dominated much of the historical landscape of ECCC (fig. 6.10). Four native perennial grasses are relatively common today, *Nassella pulchra, Elymus multisetus, Poa secunda,* and *Melica californica,* which Ertter and Bowerman (2002) presume to be remnants of the original cover. Frequent comments about "timberless land" (Kip [1850]1946), "grassy plain" (Matthewson and Allardt 1862) and "treeless hills" (*Byron Times* Fifth Booster Edition 1916a) suggest a natural vegetation distribution of the northern part of ECCC that contrasts against the wooded East Bay hills (a difference some commented on). Relatively treeless foothill lands were noted by Spanish explorer Fages in 1772 – "the soil appeared good and rather grassy but scare in wood" (Stanger and Brown 1969) – and four years later Anza recorded traveling "over a very sterile and dry plain" as he traveled east towards Antioch (Brown 1998). Brewer in 1861 bemoaned the treelessness: "through the Kirker Pass, then among rounded hills, almost bare of grass or herbage, in places entirely so – no trees to cheer the eye, no water in the many canyons and ravines" (Brewer 1974).



Our historical mapping shows that grassland covered 97,000 acres, or 52% of the study area, compared to 58,800 acres, or 34% today (see fig. 6.6, table 6.2). Grassland occurred in about 37% of the montane region, in contrast to 75% in the foothill region. The coverage today remains at 36% in the montane region, but has decreased to 62% in the foothills. The lower elevation plains were composed of about 42% grassland historically, compared to 27% today. Grassland has been disproportionately affected by urban development as residential subdivisions have largely occurred within the plains and foothill regions of the study area.

Grassland tends to largely dominate clay-rich, deep soils (Holstein 2000). The 1939 soil survey describes the Altamont clay, which extends through the majority of the foothill region, as "covered with grass, together with a few oaks and patches of chamiso *[sic]* or other brush" (Carpenter and Cosby 1939). The grass in this region was also described as supporting "a luxuriant growth of alfilaria and wild oats" ca. 1853 (Hulaniski 1917). This account notes in particular that "on the wash of Sand Creek, where the soil had been flooded, the oats were so tall that the antelope and cattle made trails through and underneath them, and it was possible for a horseman to lap the heads of the oats together over his shoulders while sitting on his horse" (Hulaniski 1917). While non-native species are described here, these accounts suggest that the richer soils of the alluvial plains, with presumably higher moisture content, provided a more vigorous growth of herbaceous vegetation. Moving toward the upper elevations, grassland intermixed with woodlands and savannas at a small scale (smaller patch size), and occurred predominantly on south slopes due to topographic (greater solar insolation) and edaphic effects (Holstein 2000). Grass appears to have been less robust in these upper elevations with "only a scanty growth of grasses fit for sheep pasture," as GLO surveyor Wackenreuder reported in 1875(a).

Both perennial bunchgrasses and annual forbs were likely a part of the historical grassland (fig. 6.11). Holstein (2000) identifies this region as a "potential forbland corridor" due to a climate with insufficient rainfall to support extensive perennial grasses. Elk and other megafauna browsed on these grassland species, which likely had a profound effect on plant species distribution and abundance (Benyo 1972, Edwards 1992, Hamilton 1997, D'Antonio et al. 2000, Shiffman 2007, Barry et al. 2006). Bidwell observed a "large herd of elk and wild Horses, grazing upon the plain" when he passed through en route to Marsh's adobe in 1841 (Bidwell [1842]1937). And GLO surveyor Leander Ransom remarked on "herds of elk, antelope and deer that abound here" during his survey of Mount Diablo (1851). Changes in grassland species composition occurred shortly after Spanish contact in ECCC as elsewhere in California (Mensing and Byrne 1999). Non-native wild oats, mustard and other invasive grasses were commonly found by the early 1800s. GLO surveyors frequently report of plains covered by wild oats and Wilkes, during his 1845 exploring expedition, found the hills "thickly covered with wild oats" (Wilkes 1845).

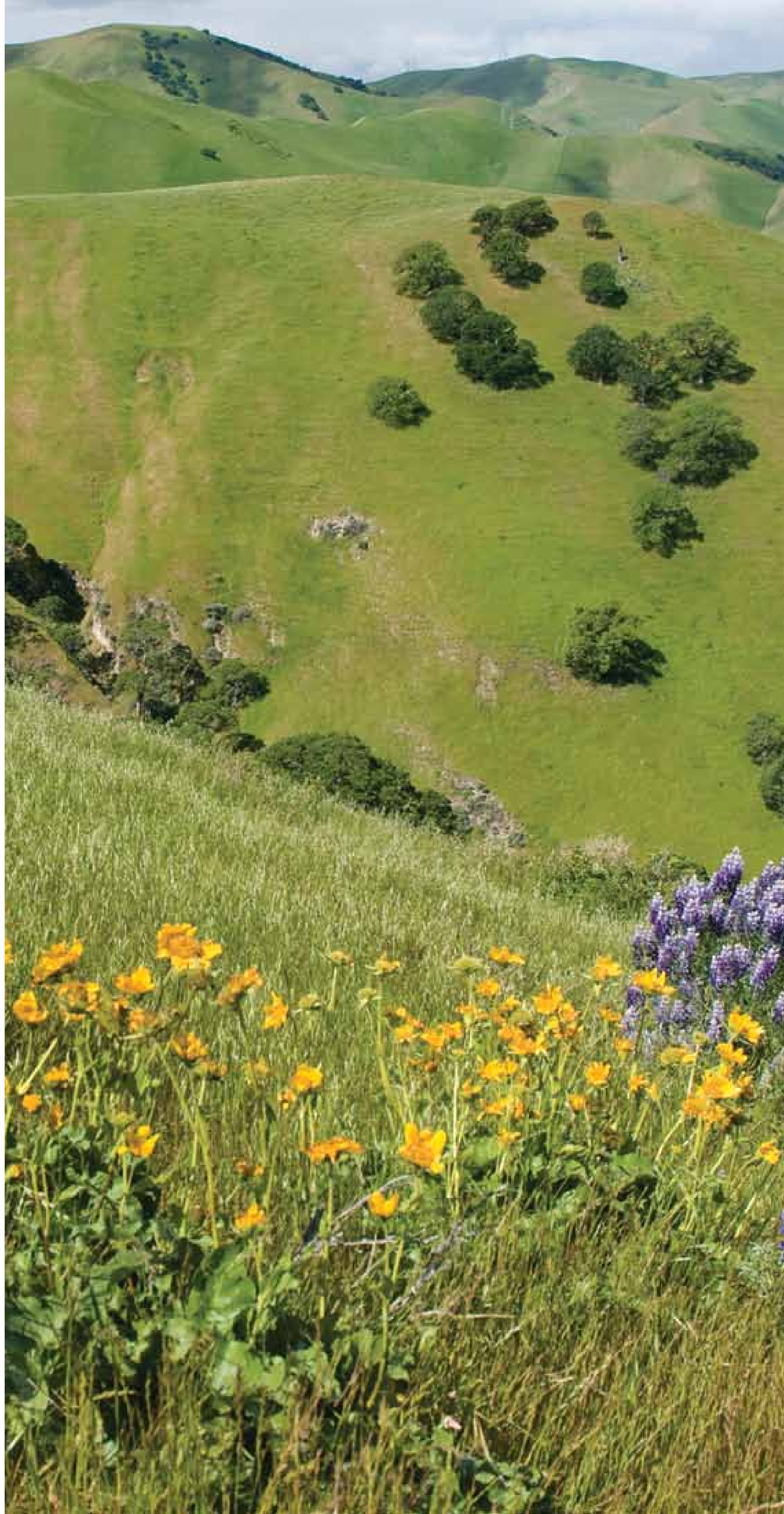


Figure 6.11. Grasses and forbs. Many native forbs are still present. This photo from the Black Diamond Mines regional park shows a mix of grasses and forbs with rangelands and scattered oaks in the background. (Photo April 6, 2008, by Scott Hein, www.heinphoto.com)

Woodland and Savanna

Regional Spatial Patterns

Overall, we mapped 25,300 acres of woodland and 17,000 acres of savanna, compared to 24,200 acres of woodland and 5,900 acres of savanna in the recent HCP mapping of the area (Jones & Stokes 2006; see fig. 6.7, table 6.2). This mapping was based largely on 1930s data. Our mapping shows that woodland and savanna covered the majority of the montane region, with 47% of the area (16,200 acres) as woodland and 6% (2,200 acres) as savanna. This is compared to 45% (15,500 acres) and 9% (3,000 acres) today, respectively. In the foothills, we mapped 15% of the area (9,000 acres) as woodland and 7% (4,500 acres) as savanna. HCP mapping shows 14% (8,600 acres) as woodland and 5% (3,100 acres) as savanna for this region. Estimates for the plains region, which were generally based on mid- to late 1800s sources, suggest that savanna covered 11% of the region (10,300 acres) historically. Only 0.1% of the plains (80 acres) is mapped as savanna today.

Summarizing the data using the Manual of California Vegetation (MCV; Sawyer et al. 2009) alliance classification that had been assigned to the VTM species assemblages by the UC Davis ICE group, we found that montane region Manual of California Vegetation (MCV) alliance woodland and savanna types that covered more than 2% of the area were Blue Oak Woodland (22%), Coast Live Oak Woodland (7%), Mixed Oak Forest (3%), and Interior Live Oak Woodland (3%). In the foothills, Blue Oak Woodland covered 11% of the area. Areas without VTM information make up about 16% of the montane and 13% of the foothill region, caused by areas of no data in the VTM and relicts of the VTM adjustment process (fig. 6.12).

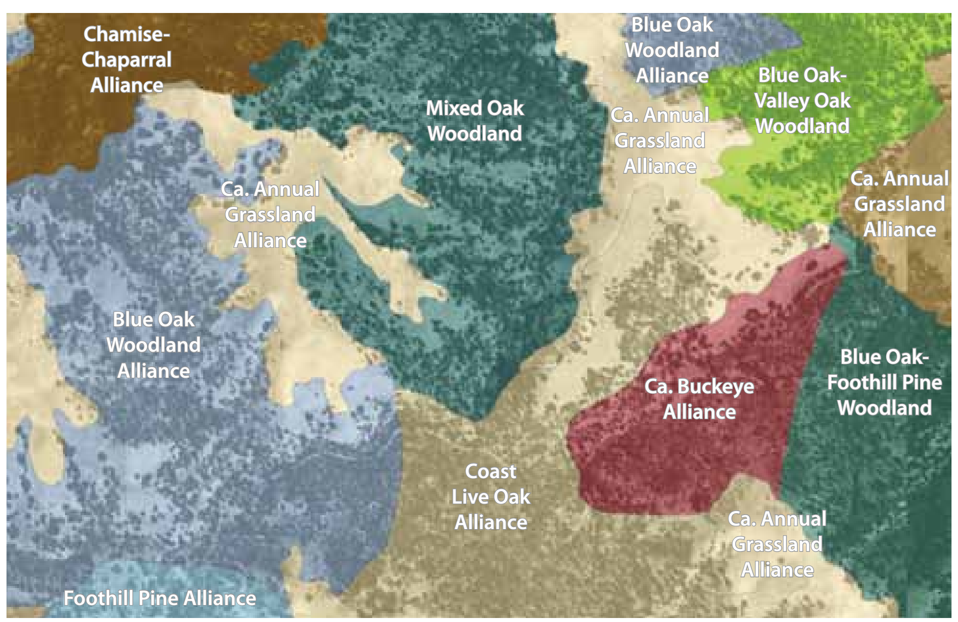


Figure 6.12. Historical habitats attributed by VTM classification. This area in the upper elevations of Mount Diablo shows the detail available from the 1930s VTM mapping (MCV classification shown here) in combination with the mapping accuracy possible using historical aerial photography.

Some conversion of savannas and woodlands to less dense habitat types occurred in all regions. In the plains, 430 acres (0.6% of the region) of savanna were converted to grassland. Our mapping shows 390 acres (0.6% of the region) of foothill savanna shifted to grassland, while only 66 acres shifted to woodland. For woodland, 160 acres (0.3% of the region) shifted to savanna. In the montane region, conversion of savanna to grassland and to woodland was similar (100 acres and 140 acres respectively). Woodland conversion to savanna was much greater (850 acres or 3% of the region). Significant clearing and thinning of oak woodlands has occurred in the upper watershed of Marsh Creek, particularly in Morgan Territory. Some clearing is also evident in the 1939 historical aerial photography. One large area, in particular, is between Sand and Deer creeks (fig. 6.13). Elsewhere, changes in tree cover can be seen following parcel boundary lines and around mining towns (Adams pers. comm.).

This trend of thinning tree cover, with coversion of woodlands to savannas and savannas to grassland, likely persisted throughout the late 1800s and early 1900s as a result of mining and settlement (Adams pers. comm.). Therefore, the mapped extent of woodlands and savannas, primarily mapped using the 1939 aerial photography, likely underrepresents the presence of these habitat types in the mid-1800s landscape. Based on calibration against narrative descriptions and examination of the historical aerials for obvious areas of cutting, we expect these changes to be fairly localized, although the historical record is not definitive. As might be expected, the greatest areal loss of woodlands and savannas was to urban and agricultural uses, especially in the lower elevations.

Figure 6.13. Area of change prior to 1939. In the center of the image, extensive areas of stumps and/or small trees are seen around the chaparral. Large trees cover these areas today. (USDA 1939, courtesy courtesy Contra Costa County and Earth Sciences & Map Library, UC Berkeley

Using the bearing tree dataset as a calibration against the habitat mapping, we found that only 33 out of 318 bearing trees with azimuth and distance information were more than 500 ft outside of mapped savanna or woodland polygons, which lends solid early support for our mapping. Most of those 33 trees fell within the foothills and plains region, particularly within the Marsh Creek and Kellogg Creek watersheds (fig. 6.14). This could suggest that these areas may have had more trees historically than were apparent in the 1939 historical aerial photography. However, it is perhaps more likely that these GLO trees are the widely spaced trees evident in the 1939 aerials that were not mapped as savanna due to the extremely low density.

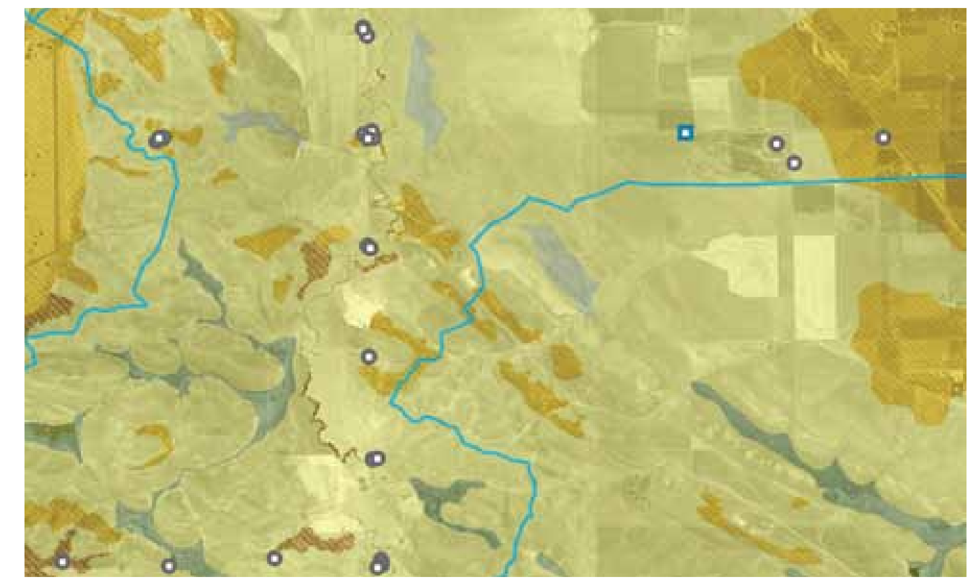


Figure 6.14. GLO bearing trees shown in mapped grassland. This area in the foothills near Marsh Creek shows that GLO surveyors did find some bearing trees in areas mapped as grassland, possibly indicating a higher density of trees in the mid-1800s in comparison to the 1939 aerial photography.

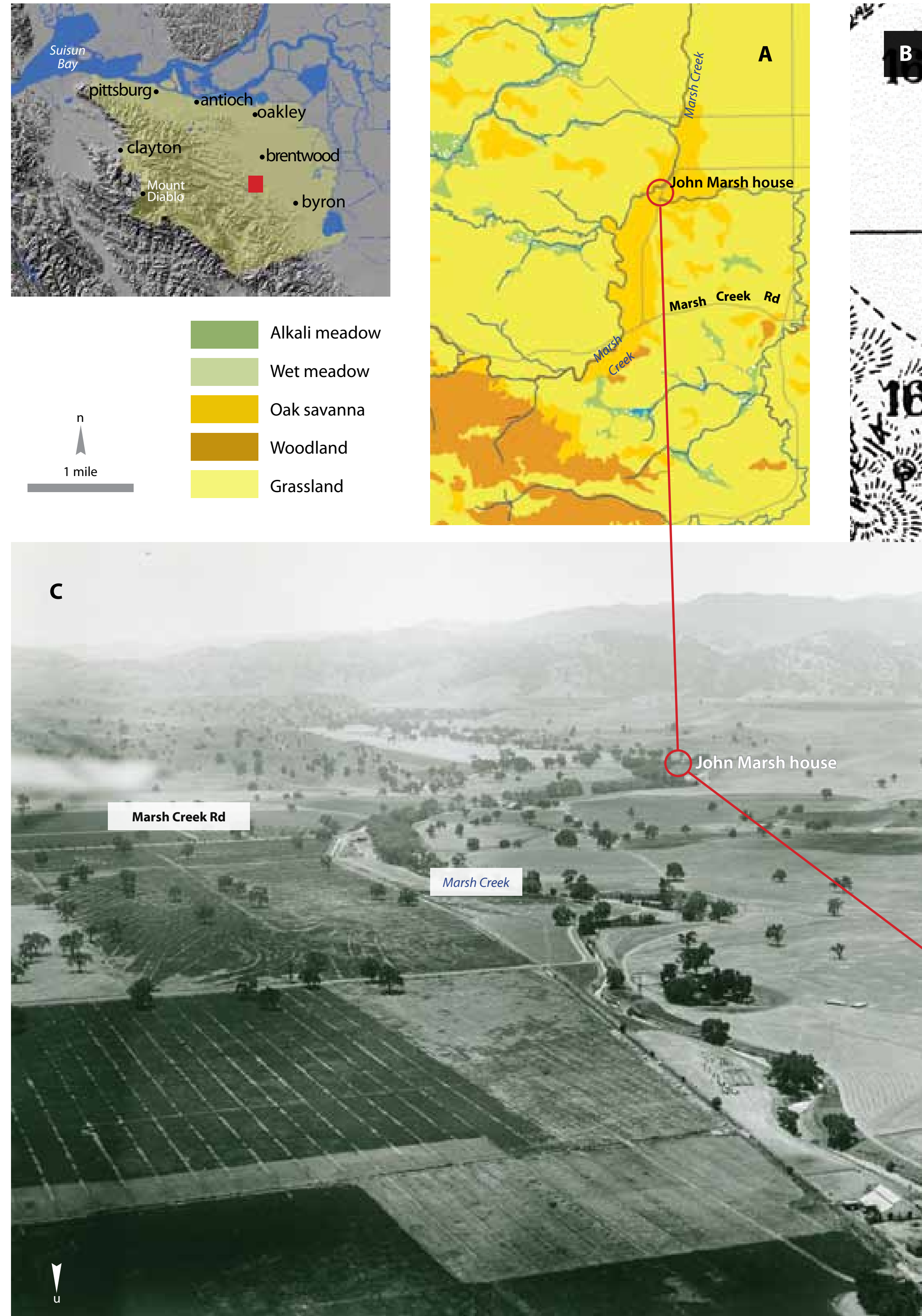
Alluvial plain oak savannas are currently a rare habitat, but historically occurred in many parts of the study area. Savannas were documented along the small alluvial valleys as well as in a broad swath along the eastern margin of ECCC. The southern tip of this region of oaks reached almost to Byron and was known as 'Point of Timber' both due to its shape and the fact that it was the first significant stand of timber encountered when coming from the south. A number of sources confirm the presence of large oaks in this area. GLO Surveyor Norris (1851) described the eastern portion of these trees as "thin but very large" and noted two bearing tree white (likely valley) oaks with six foot diameters 210 feet apart. Continuing north in the vicinity of Point of Timber, Surveyor Dyer (1862a) described "scattering oaks." He also noted of this township (T1N, R2E) as a whole that "it was at one time covered with a heavy growth of oak timber." Near Oakley, explorer Font (1776) recorded "we turned to the east-southeast and traveled this way some three leagues [1.5 miles], having on our right a grove of oaks which runs for about six leagues [3 miles] along the foot of the sierra to the south" (Font and Bolton 1933). Almost a century later, General Land Office surveyors note a transition from chaparral to an "oak orchard" as they "leave chemisal *[sic]* and enter scattering oak timber" near present-day Lake Alhambra (Ransom 1851, Wackenreuder 1875b), an area that is also described by explorers and in land grant testimony (Whitcher 1853b, Smith 1866, Font and Bolton 1933). These trees appear to have been mostly cleared in the space of a few decades, as agriculture, particularly wheat and orchards, spread east.

Another distinct alluvial oak savanna occurred along Marsh Creek, extending above and below present-day Marsh Creek Reservoir (fig. 6.15). Geologist William Brewer in 1862 described emerging "into a flat of perhaps two or three hundred acres surrounded by low rolling hills and covered with oaks scattered here and there, like a park. And such oaks! How I wish you could see them – nearly worthless for timber, but surely the most magnificent trees one could desire to see" (1974) The *Contra Costa Gazette* (1887) described "great oaks which crowd the entrance to the valley and wander out on to the plains;" these trees are also depicted in George Russell's ca. 1925 oblique photos of this region and on historical maps (Brown 1912, Whitcher 1853a). An 1881 confirmation map depicts scattering trees over an area of 500-600 acres in this valley and extending into the Marsh alluvial fan, supporting our mapping of low-density oak savanna (Von Schmidt 1881).

In addition to these areas, one of the more prominent oak savannas (320 acres mapped) was located within the valley now occupied by the Los Vaqueros reservoir. Within this area, the Wieslander VTM mapping identified both blue and valley oaks.

Early accounts of the general distribution and character of ECCC provide complementary perspectives on vegetation patterns. These sources tend to paint the landscape in extreme terms, both glowing and critical. Most of those discussing the majesty of large, grand oaks or "fields that look like an old park" (Smith and Elliott 1879) focus on the lower elevations, regions that, today, are mostly developed. For instance, an 1879 history of the county declares that "there are no heavily timbered tracts in the county," but then notes that "nearly every valley is dotted over with majestic oaks of several varieties" (Smith and Elliott 1879). To another, the landscape evoked a similar image; "a broad and well-watered plain, covered with many groves of magnificent oaks" (Buffum 1933).

Written sources tend to support the mapping and the overall vegetation patterns that exist today in the undeveloped areas of the foothills: they are generally unimpressed with the tree cover and often discuss scattering oaks and areas of little or no timber (6.16). Landscapes often described as containing groves of grand trees on the plain



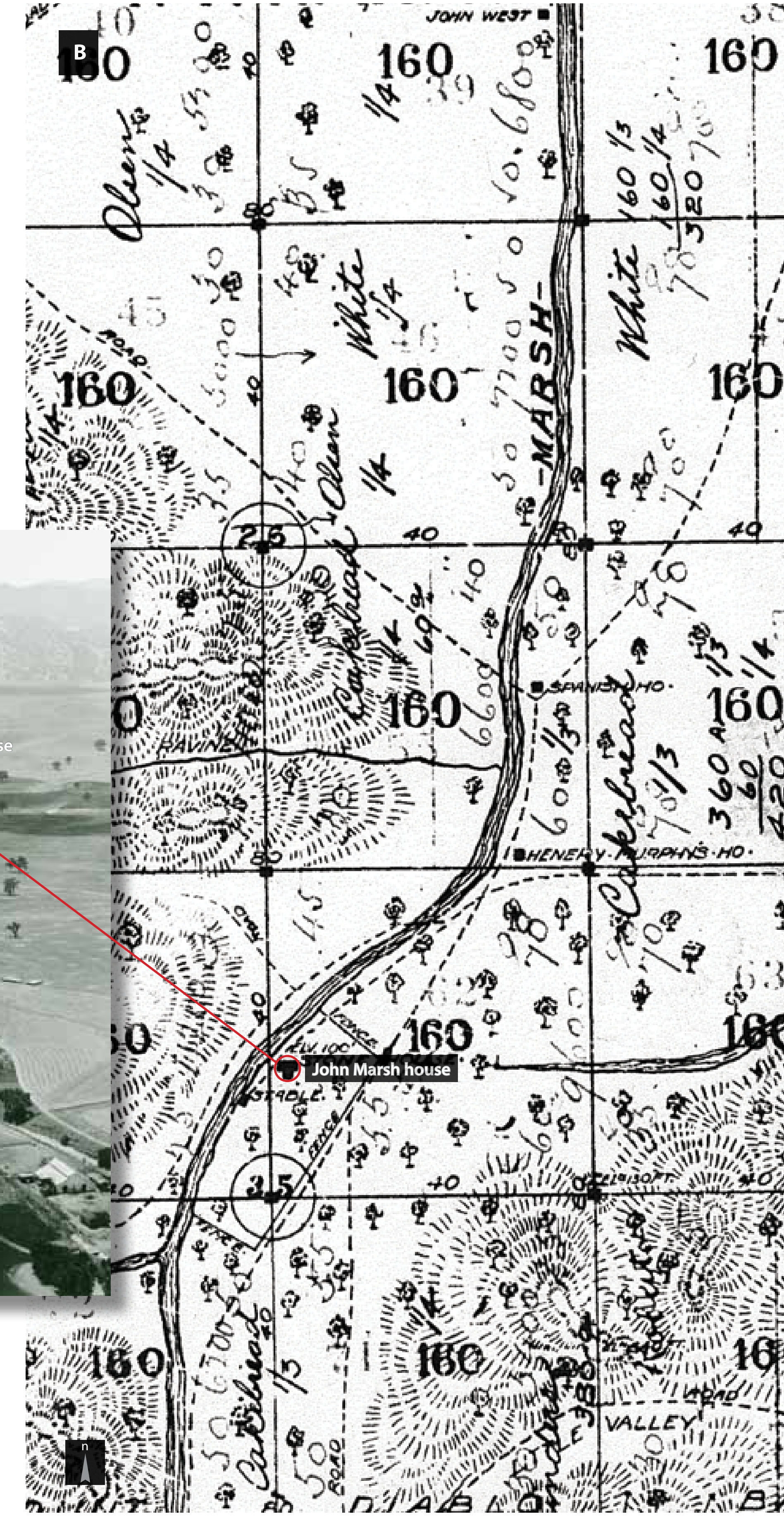


Figure 6.15. Marsh Creek valley oak woodland and savanna. A) Historical habitat map showing savanna mapped along the Marsh Creek alluvial valley. B) 1881 confirmation map depicting scattered trees along the same Marsh Creek alluvial valley. C) Oblique photography looking upstream towards the same Marsh Creek alluvial valley with oak distribution dense along the riparian corridor and sparser along the valley. Concord Ave can be seen in the foreground. The red circles link the same location across the three images. (B: Von Schmidt 1881; C: Russell ca. 1925, courtesy of the State Lands Commission)

contrast with the frequently described ECCC foothill landscape of "few scattered oaks" (Bidwell 1937) or "scattered oaks with a ground cover of alfileria, bur-clover, and wild oats" (Carpenter and Cosby 1939).

One of the more unfavorable accounts with regards to timber quality in the foothill and montane regions is that of Leander Ransom, whose 1851 GLO survey established the Mount Diablo meridian (see p. 11). He found that "the want of suitable timber for posts proved another serious difficulty, and even where it was found, you seldom met with a limb or branch more than 2 feet in length which was even tolerably straight" (Ransom 1851). He further stated that Mount Diablo "has but a small amount of timber of any kind growing either upon the mountain ranges or in the valleys" (Ransom 1851). The scarcity of timber is important to Ransom because it meant that "seldom did we meet with trees near enough to our line for bearing trees" and "our line was run for miles without meeting a tree that it was necessary to mark as coming within the scope of our work" (Ransom 1851). This scarcity of trees is supported overall by the GLO survey dataset, where only 18 line trees were recorded for the whole of ECCC. However, in the same description he does use grander terms for denser areas: "where the timber is most dense it resembles in heights and general appearance the old irregular orchards in New York, planted by the French before the Revolution" (Ransom 1851).

Species Composition and Size Class

The GLO tree dataset of the mid- to late 1800s includes 352 trees and 10 recorded species: white oak (interpreted as blue or valley oak), red oak (interpreted as blue or valley oak), live oak, black oak, pine, maple, laurel, cedar, buckeye, and sycamore (fig. 6.17). Of these trees, 65% were recorded as white oak. Most of white oaks are from the foothills and montane regions, so presumably the majority of these trees are blue oaks. The next largest group is live oak, which comprised 19% of the dataset. Pines and buckeyes each comprise 2% of the dataset. The plains region GLO trees were almost exclusively oaks, with about 20% each of red oak and live oak recorded. Trees recorded within the foothill region were about 75% white (presumably blue) oak, 10% live oak, with some sycamore and buckeye. As would be expected, the montane region has the most diverse range of trees, with nine species represented, though over half were identified as white oaks (fig. 6.18).

The VTM dataset contains more detailed information about species, which has been translated into MCV alliance types. Each mapped polygon was labeled with the dominant species, which we retained in our effort to refine mapping using historical aerial photography. For example, in an area where the GLO survey recorded several pine trees and a live oak as bearing trees, the VTM dataset identified blue oak, live oak, and pine as the dominant tree cover. Summarizing vegetation type at the VTM MCV alliance level supports that the Blue Oak Woodland Alliance dominates both the foothill and montane wooded areas (80% and 48%, respectively, for those areas attributed

Figure 6.16. Scattered oaks. Winter rains tranform the yellow grasslands of ECCC to bright green. These images show grassland (with patches of wetlands) and scattered oak savanna transitioning into woodland and chaparral. (Top: March 4, 2010, by David Ogden, Save Mount Diablo; Bottom: March 24, 2002, by Scott Hein, www.heinphoto.com)

Table 6.3. Acreage summarized by MCV alliance type. Summed acreages are included for the foothill and montane region.

Class (Sawyer et al. 2009)	Acres in Foothill	Acres in Montane
Barren	135	24
Bigberry manzanita chaparral	2	17
Birch leaf mountain mahogany chaparral		86
Black sage scrub	3	20
Blue oak woodland	7,199	7,405
California bay forest	0	11
California buckeye groves	209	603
California juniper woodland		87
California sagebrush scrub	14	32
California sagebrush-black sage scrub	21	5
Canyon live oak forest		76
Chamise chaparral	260	1987
Coast live oak woodland	98	2419
Arctostaphylos manzanita Provisional Shrubland		18
Coulter pine woodland		33
Ghost pine woodland	52	254
Interior live oak chaparral		199
Interior live oak woodland	585	847
Mixed oak forest	72	1070
Toyon chaparral		28
Valley oak woodland	388	356
Fremont cottonwood forest, Red willow thickets, or Sandbar willow thickets	8	

with VTM info). Other alliances comprising greater than 5% of the montane region include the Chamise Chaparral, the Coast Live Oak, the Interior Live Oak Woodland, and the Mixed Oak Forest (Sawyer et al. 2009; table 6.3). In the foothills, only Interior Live Oak Woodland and Blue Oak Woodland are over 5%. Further analysis of these datasets, including VTM plot data, could be carried out and would allow for a more comprehensive synthesis. More detailed descriptions of species composition can also be found in the ECCC HCP/NCCP (Jones & Stokes 2006) as well as Ertter and Bowerman's book, *The Flowering Plants and Ferns of Mount Diablo, California* (2002).

The GLO bearing tree dataset also allows for examination of diameter at breast height (dbh) distribution. We examined just oak species, and found that the 315 oaks with diameter data had an average dbh of 21 inches. The size distribution differs between geomorphic units, with 20-30 inches being the most common size class in the plains region, and 10–20 inches the most common class in the foothills and montane regions. Also, no oaks larger than 40 inches were recorded in the montane region while one oak with an 8 ft dbh was found in the foothills and several up to 6 ft dbh were found in the plains (fig. 6.19). Some areas were characterized by particularly large trees. For example, of the 12 GLO bearing trees in the area of the Point of Timber, all were found to be 20 inches in diameter or greater, with an average of 46 inches.

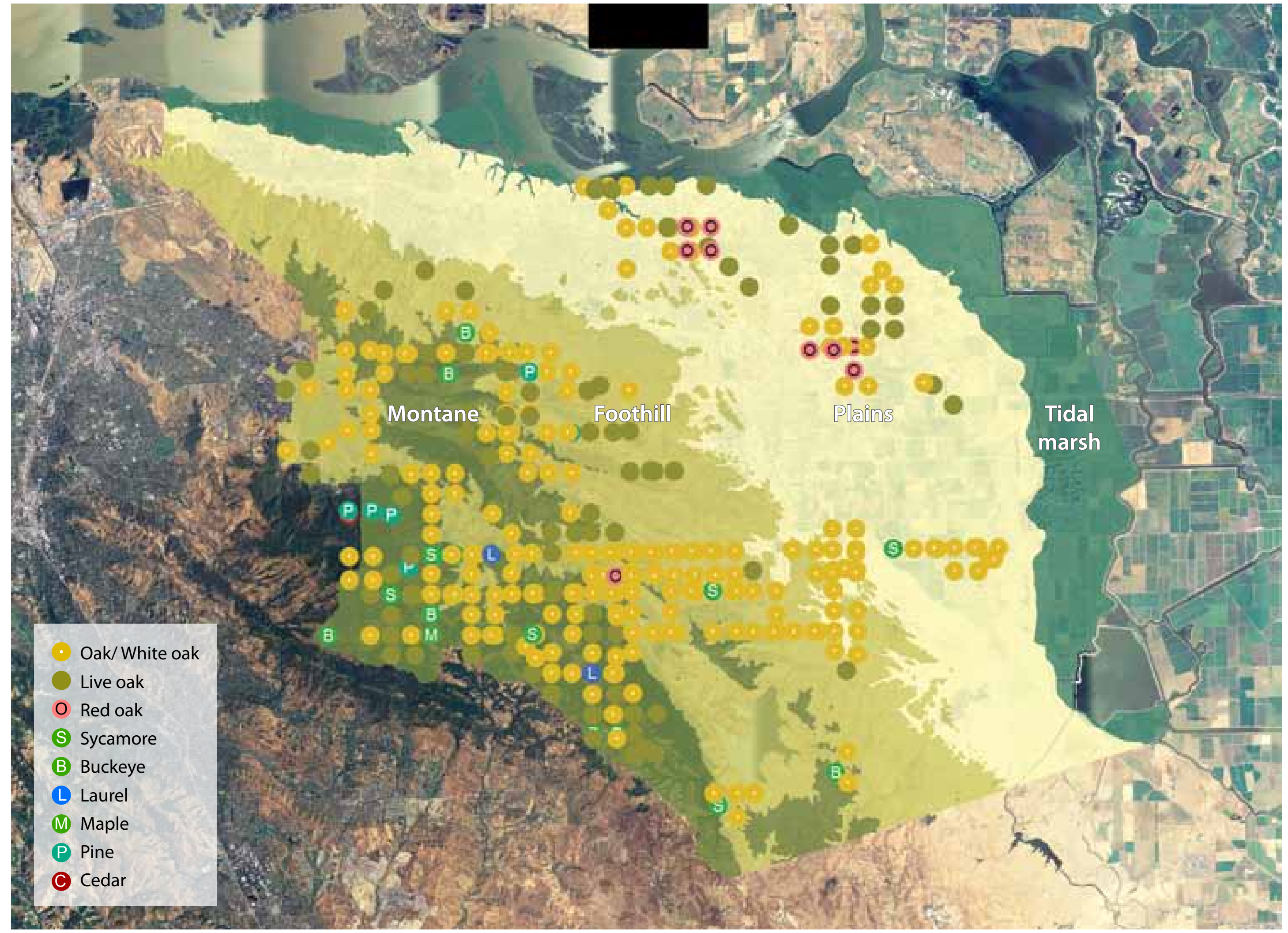


Figure 6.17. Distribution of GLO trees. (above) The GLO survey tree dataset displayed over geomorphic region showing basic distribution and species. The greatest number and diversity of species are found in montane (dark green) and foothill (light green) region. White oak (valley oak), red oak (valley or blue oak), and oak (undifferentiated) reflect the GLO naming conventions, based on East Coast trees. (overlaid on USDA 2005, courtesy of NAIP)

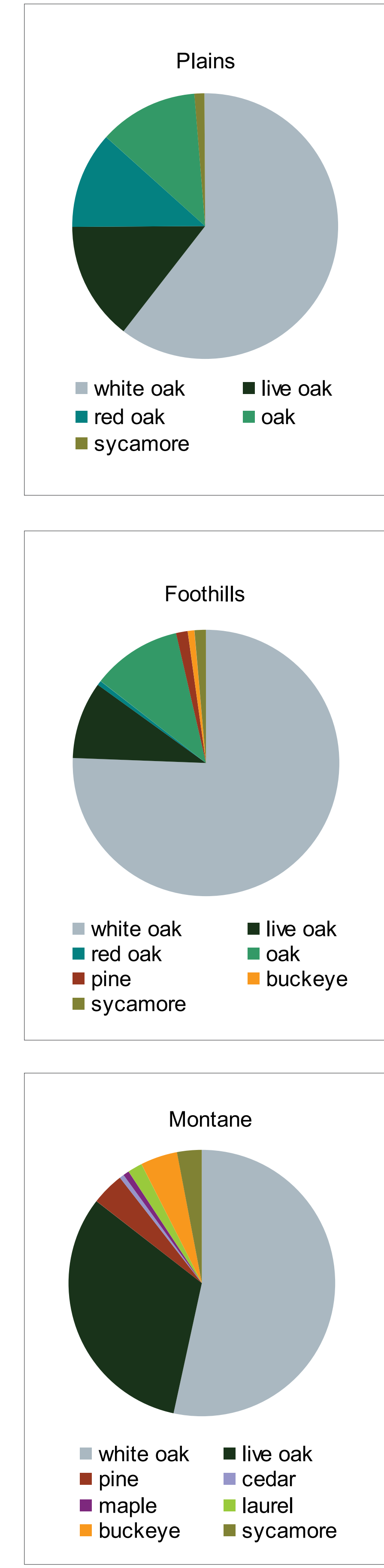


Figure 6.18. GLO tree species by geomorphic unit. (far right) Pie charts show the composition of GLO tree species, broken down by geomorphic unit. Size is not relative to the total number of recorded trees. White oak (valley or blue oak), red oak (valley or blue oak), and oak (undifferentiated) reflect GLO naming conventions..

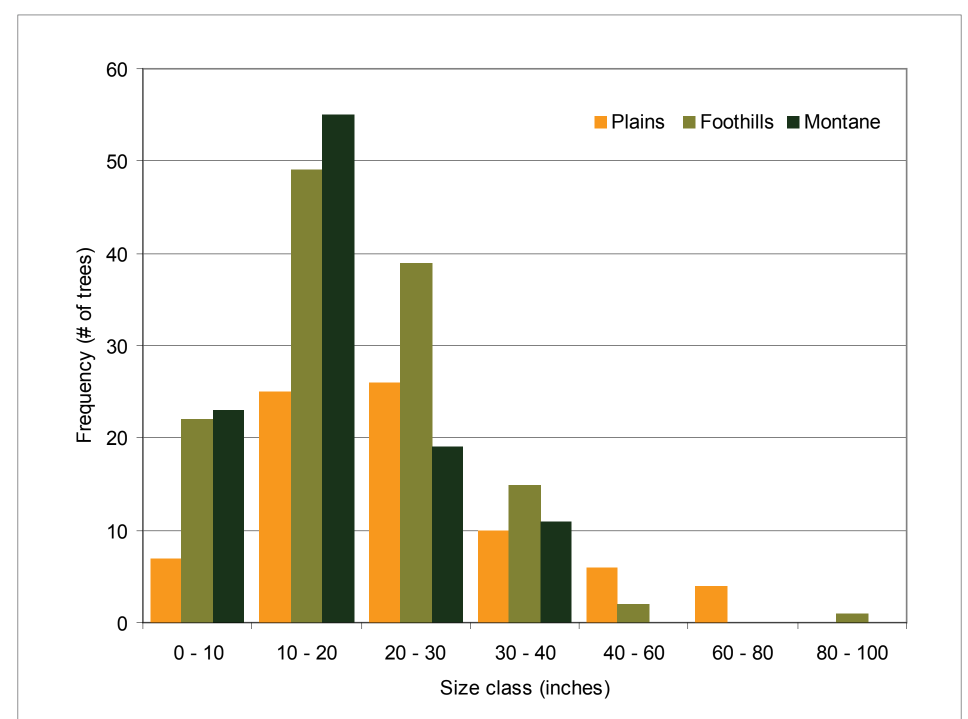


Figure 6.19. Tree sizes. (right) Size distribution of trees by geomorphic units. The largest trees were found in the plains region.

Density Estimations

Early descriptions of density patterns identified groves as important features in the landscape, suggesting patterns of greater and lesser tree density. Some of the savanna descriptions suggest areas of denser groves with woodland characteristics; it should be assumed that smaller patches of woodlands occurred within the large region of mapped savanna. Along the alluvial plains, the arrangement of trees is described as "a park" where "they are disposed about the plains in most lovely groups, masses or single ones" (Smith and Elliott 1879; an identical description was used in Napa Valley, which suggests the authors may be describing a Bay Area-wide pattern; Smith and Elliott 1878). One of these groups, in the vicinity of Point of Timber, was composed of at least "twenty-five of those grand old oak trees, whose boughs gracefully sweep down and reach the ground"(Smith and Elliott 1879). This description is characteristic of other valley settings of the Bay Area: widely spaced, large valley oaks in a savanna setting. Another account from the Daily Alta California states that "the plain is interspersed with clumps of evergreen oaks, which look at a little distance like our apple orchards in the Atlantic States" (*Daily Alta California* 1860). (While this account emphasizes live oaks, the GLO data show that deciduous, i.e., valley/blue oaks were more prevalent.) Groves apparently became quite dense in some areas, such as the Byron area, described as "so dense it is said their tops seemed to grow together" (Hill 1990).

Table 6.4. Average density estimates from GLO dataset. Data are averaged by region to show relative differences in density across geomorphic units. Estimates from both the Morisita (1957) and Cottam and Curtis (1956) methods are shown for comparison.

	DENSITY (Morisita method)			DENSITY (Cottam and Curtis method)		
	No. of survey points	Density (trees/ac)	Error in density	No. of survey points	Density (trees/ac)	Error in density
Plain	21	2.6	0.9	39	6.6	2.1
Foothill	39	9.3	2.2	70	12.4	4.2
Montane	29	9.2	4.1	76	21.1	4.8

Table 6.5. Density of individual patches. We estimated tree density in small stands of live oaks found on patches of isolated interior dune sand (see p. 90). The numbers below reflect the number of trees at each of four nearby locations. Area was approximated by drawing a small polygon around the group of trees.

Location	Area (acres)	Source	# of trees	Density (trees/acre)
West of Antioch - large oak patch	43.4	Davidson USCGS 1887	22	0.5
West of Antioch - large oak patch	43.4	San Pablo-Tulare Railroad n.d.	15	0.3
West of Antioch - smaller oak patch	3.5	San Pablo-Tulare Railroad n.d.	5	1.4
Antioch Dunes	86.9	Davidson USCGS 1887	76	0.9

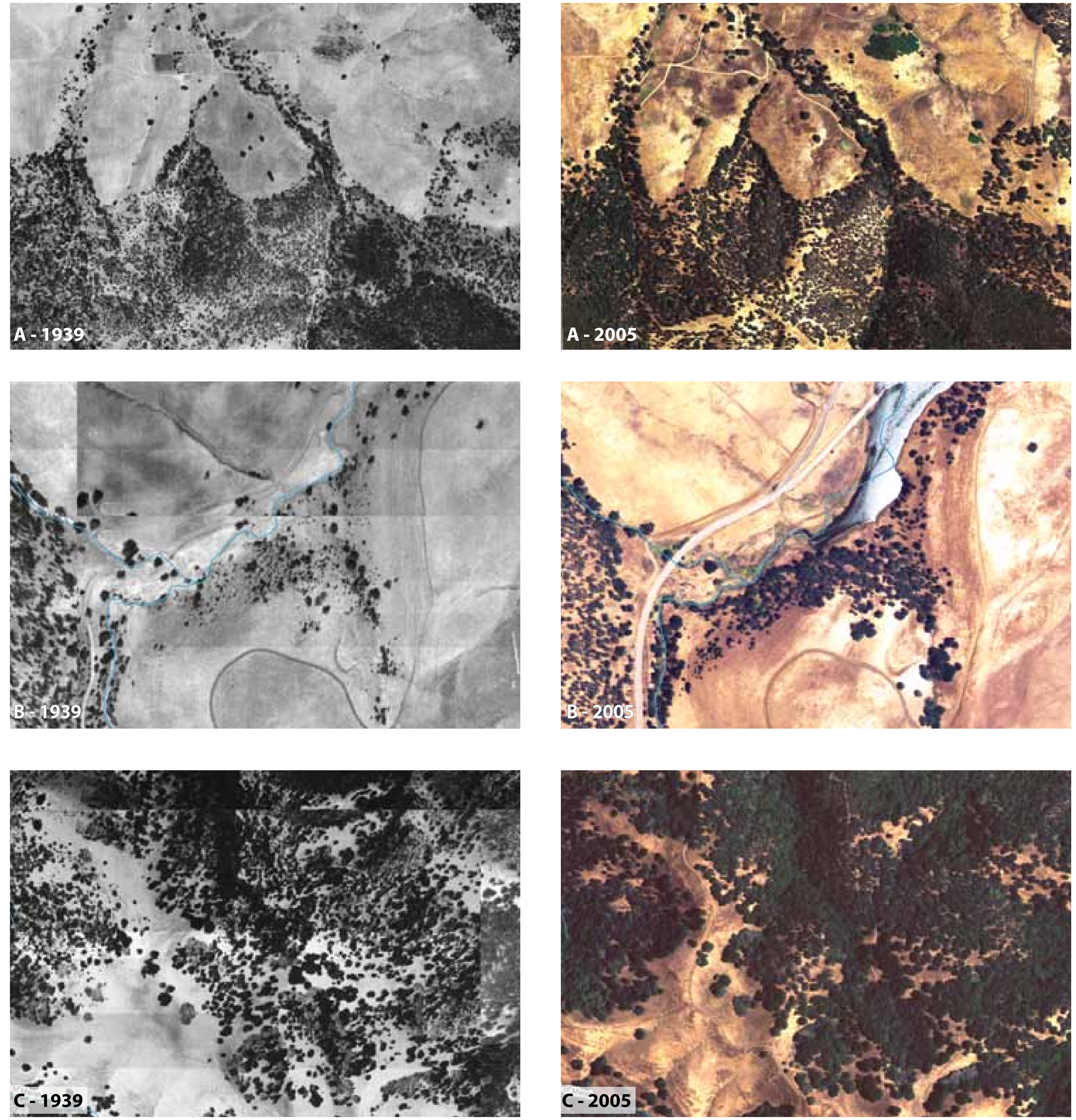


Figure 6.20. Examples of possible shifts in oak woodland density. (above) Visible differences between the 1939 and 2005 imagery suggest that canopy sizes are increasing, as opposed to increased stand density. However, such apparent changes are difficult to interpret given differences in the imagery. Additional research through remote sensing techniques and on-the-ground field work to determine age structure would be necessary to address these perceived trends. A) Upper Mount Diablo Creek watershed appears to show less space between tree canopies in contemporary imagery. B) A small stand of apparently smaller trees in the historical imagery seems to have grown in by 2005. C) A relatively dense woodland in the upper Marsh Cr watershed becomes even more dense as open spaces visible in the historical imagery are filled in. (Left: USDA 1939, courtesy of CCC and Earth Sciences & Map Library, UC Berkeley; Right: USDA 2005, courtesy of NAIP)

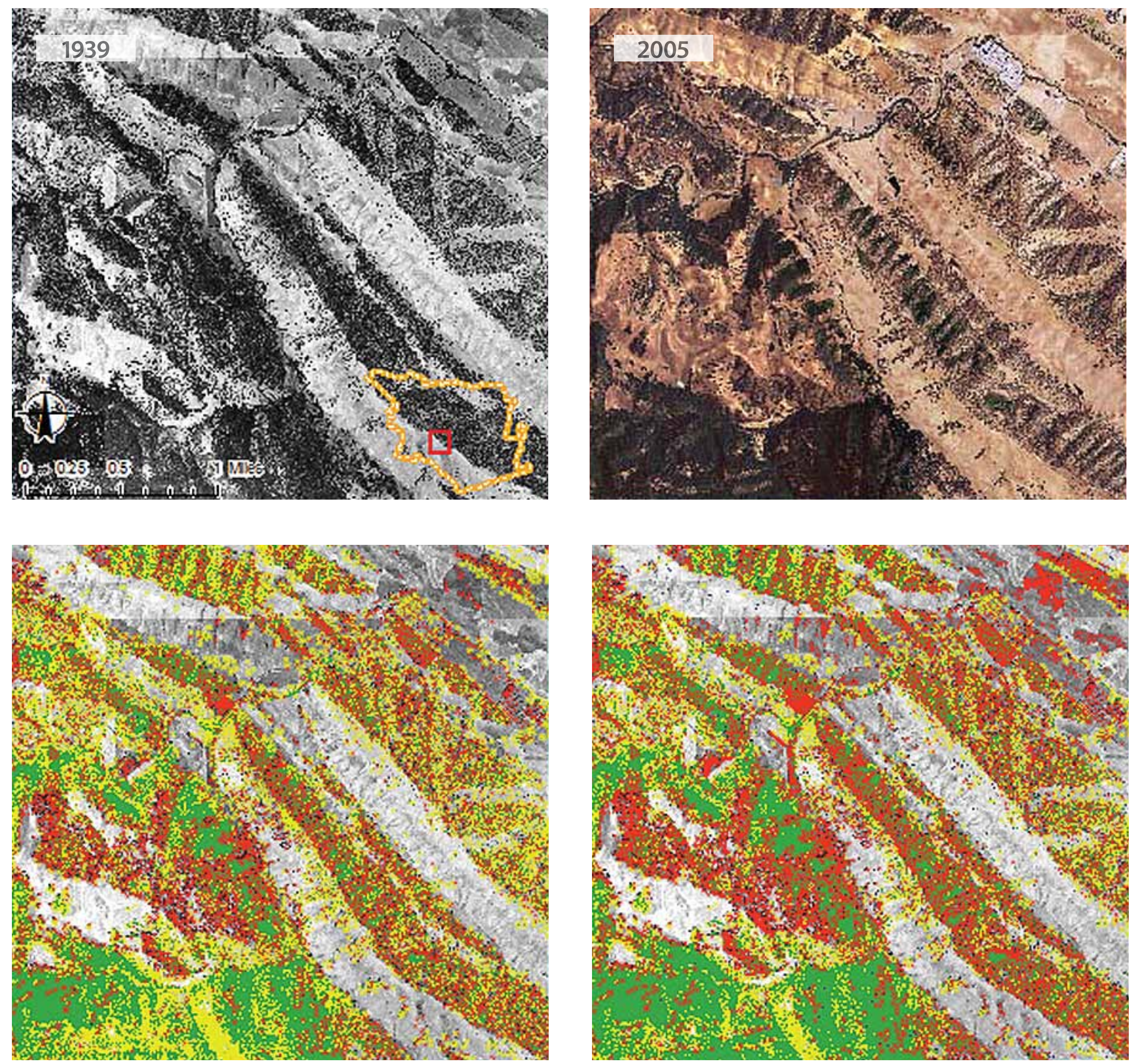
Density estimations using the GLO survey bearing tree dataset (using all species) and two different calculation methods demonstrate that density was lower in the plains than the other geomorphic units, supporting the mapping of savanna along the plains (table 6.4). However, an expected higher density in the montane region in comparison to the foothills is evident only with the Cottam and Curtis method. Part of the explanation is that density variation likely occurs at smaller scales. To explore this, we noted a few visually identifiable "populations," or clusters of points, that had distinctly different density characteristics. For instance, the Point of Timber region contained five survey points with bearing trees, which were associated with the extremely low average density of approximately 1 tree/acre. This, combined with the information that these were significantly larger trees than the average oak in the study area, suggests that the Point of Timber oaks were a unique population of trees along the plains.

We used additional sources to estimate stand densities for other habitat types for which data were available. In three locations along the northern edge of Contra Costa, within the interior dune habitats, historical maps provided information showing individual trees. To estimate density, we divided the number of trees depicted by an individual source by the area of the surrounding polygon. Two independent sources mapped live oaks in the larger polygon west of Antioch, so we calculated a separate density estimate for each source (table 6.5). The distribution of roughly 0.3-1.4 tree per acre fits within our classification of savanna, but is at the lower end of estimates from the GLO dataset. USCGS maps of this era can accurately show individual trees (Westdahl 1897); however it is possible that not all trees were shown in some of these maps and our estimates are low.

Upon examination of historical aerials and comparison to modern imagery, certain density shifts are evident. In some cases, this appears to be a result of changes in tree canopy size as opposed to changes in stand density. In places, gaps between trees that were evident in the 1939 aerial photography were filled in by the time of the contemporary imagery (fig. 6.20). We were unable to assess the entire area quantitatively, and thus must caution that we are unable to state whether the majority of wooded areas have become more or less dense over the past 80 years. Follow up research including tree dating and more comprehensive spatial analysis would help establish the pattern.

Examining density changes through raster analysis can illustrate how spatially complex these changes may be. In a 8.4 mi^2 example to test methods from the Marsh Creek watershed, about 26% of the area was shown to have undergone a change from chaparral or tree cover to grassland or vice versa (fig. 6.21). While it cannot be determined with this level of analysis whether the overall trend was toward denser or less dense cover, particular areas do appear to have changed more than others (e.g., the southwestern corner appears to have proportionately more change from grassland to trees and chaparral, while just above that the trend is the opposite). Another preliminary raster analysis to detect small changes of density within particular habitat types supports the observation that some woodland areas within the uplands have become denser, not necessarily through an increase in the number of trees, but rather through a canopy size increase (fig. 6.22). The coarse assessment for this area suggests that tree cover may have increased by 10% (see fig. 6.21).

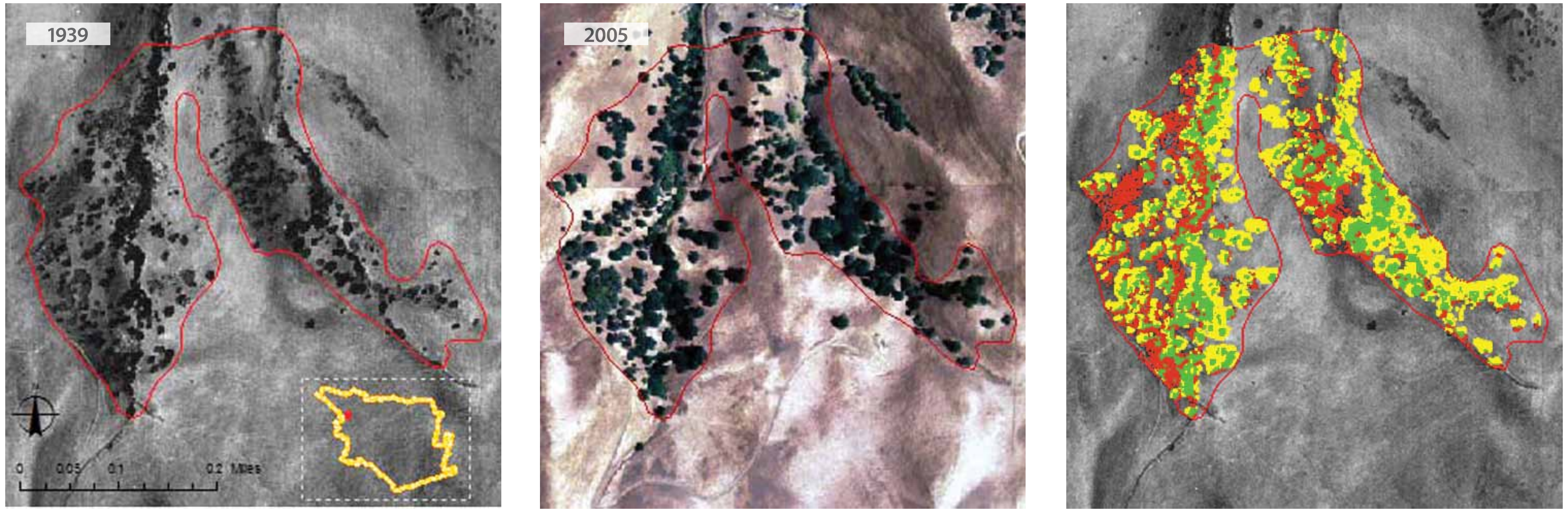
Blue oaks at a very low density (mapped as grassland) are found along much of the ECCC foothills. In some of these areas, it was possible to observe the slow loss of individual trees which had occurred between the times of the two sets of aerial photography (fig. 6.23). Such losses suggest natural mortality and the lack of seedling recruitment.



		2005	
		Cover	*No Cover*
1939	*Cover*	37.3%	12.7%
	No Cover	20.5%	29.5%

Cover to Cover (no change)
No Cover to Cover
Cover to No Cover
No Cover to No Cover (no change)

Figure 6.21. Exploring possible density change using image classification. An area of approximately 8.4 mi^2 in the foothills of the Marsh Creek watershed is shown in the 1939 and 2005 aerial imagery (top) with two preliminary analyses that used different ranges of pixel values to classify pixels as tree or scrub versus herbaceous cover (bottom). Both compare historical and contemporary cover. The first shows more change of no cover (1939) to cover (2005), indicated in yellow, while the second shows more cover to no cover change, indicated in red. At this point in time, methods do not address the challenges of differentiating between shadows versus true tree or scrub cover nor does it account for inconsistencies between the imagery taken at such different times. It does seem reasonable to note, however, that both show that more change in no cover to cover occurred in the lower left part of the image, while cover to no cover conversion seems to have taken place more in the central and northeast part of the area. (USDA 1939 courtesy of Contra Costa County and Earth Sciences & Map Library, UC Berkeley; USDA 2005 courtesy of NAIP)



Cover to Cover (no change)
No Cover to Cover
Cover to No Cover
No Cover to No Cover (no change)

Figure 6.22. Effects of changes in tree size on image classification. (above) Similar classification techniques as shown figure 6.21 were used for a single mapped woodland polygon to explore possible change as a result of larger canopy sizes. Individual tree canopies are mostly shown as no cover to cover in the image, indicating larger tree sizes in the contemporary imagery. Some error can be detected to orthorectification errors. Future analysis could assess if these are real trends through more sophisticated imagery analysis and on-the-ground field assessments to analyze tree age. It may also be valuable to explore trends by geomorphic unit or by other physical factors such as slope and aspect. (USDA 1939, courtesy of CCC and Earth Sciences & Map Library, UC Berkeley; USDA 2005, courtesy of NAIP)

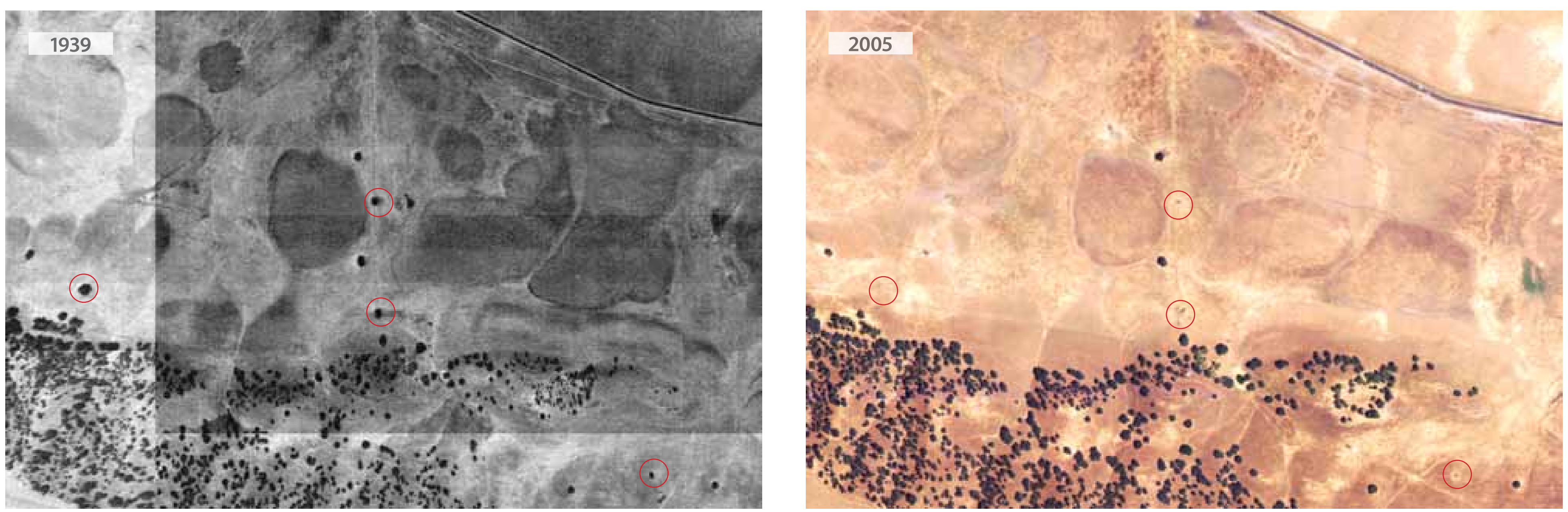


Figure 6.23. Area of individual tree loss. Although this area is mapped as grassland in both the historical and contemporary mapping, several individual trees within this grassland visible in the historical aerials are gone by the time of the 2005 imagery (trees in circled in red in historical imagery are missing in 2005). In "sparse savanna" settings such as these, tree density - while initially quite low - may have decreased substantially. (Left: USDA 1939, courtesy CCC and Earth Sciences & Map Library, UC Berkeley; Right: USDA 2005, courtesy of NAIP)

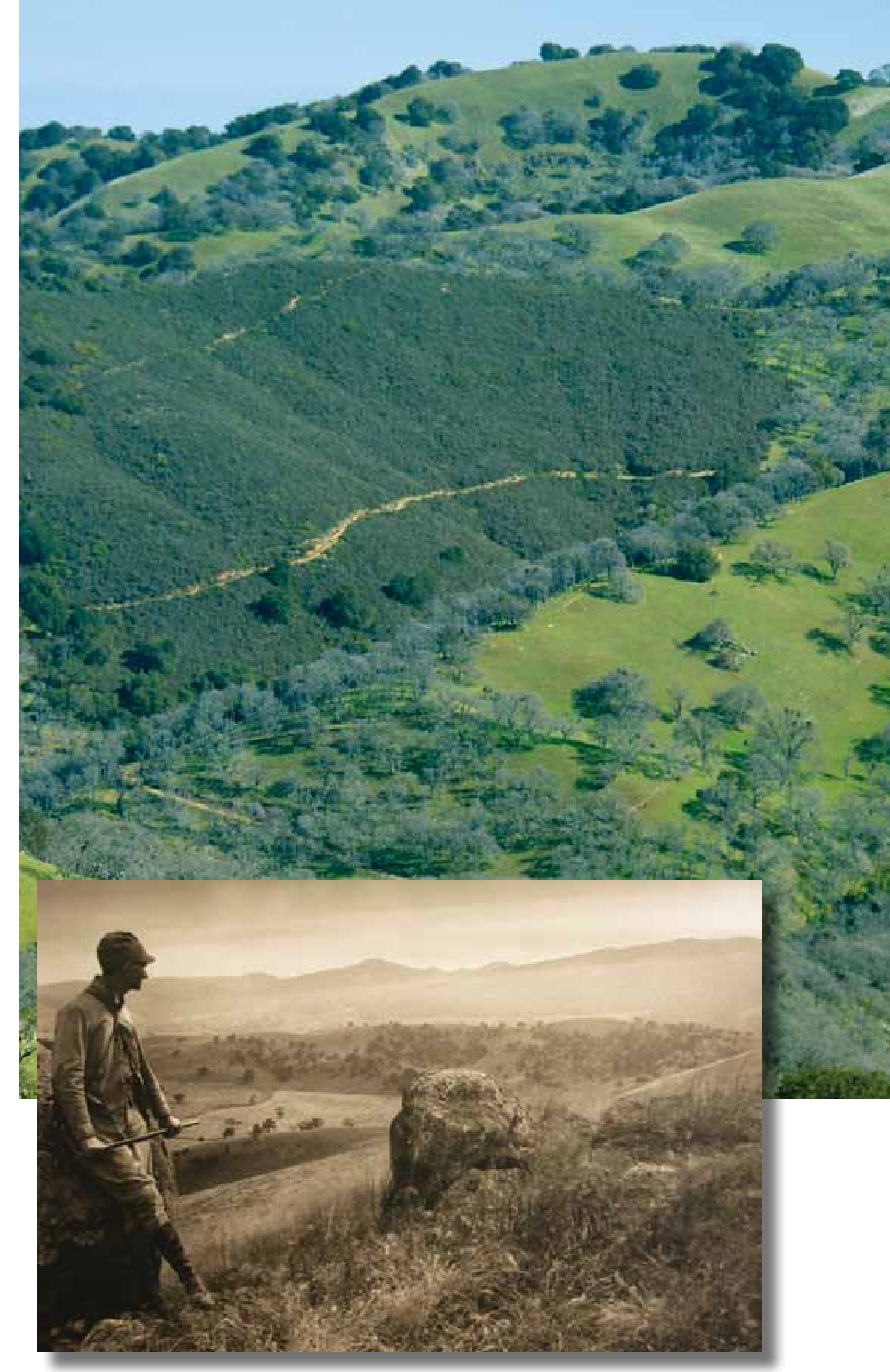


Figure 6.24. Images of chaparral. Chaparral and scattered oaks on facing hillsides illustrate the patchwork of vegetation types in the foothills of ECCC. The inset historical photo, ca. 1920, shows the view looking towards the Black Hills from the Los Vaqueros reservoir area. (Contemporary image: February 9, 2003, by Scott Hein, www.heinphoto.com; Historical image: courtesy of the California Historical Society)

Chaparral/Scrub

At the regional scale, the distribution of chaparral and coastal scrub vegetation types appears to have remained largely unchanged since the mid-1800s. Historically, chaparral covered a total of 2% of the study area, or 3,400 acres. The general distribution of chaparral/scrub is consistent with that of today. Within the foothill geomorphic unit, chaparral was a relatively minor component, yet has decreased by over 25%: we mapped 0.6% (360 acres) as chaparral, compared to 0.4% (270 acres) mapped today. About 0.1% of the foothill region converted from chaparral to grassland and 0.1% to woodland. Mapped chaparral/scrub in the montane region historically covered about 8.7% of the area or 2,950 acres, slightly more than is mapped today (8.1% or 2,750 acres). Our mapping reveals that about 0.6% of the montane region, or 200 acres, converted from chaparral to woodland. Conversion also included 0.1% to ruderal, while 0.1% of the region shifted from savanna to chaparral and 0.1% of the region from woodland to chaparral (see figs. 6.7, 6.9, table 6.2).

Chaparral and scrub vegetation is characteristically found in the upper elevation, steep southerly-facing slopes of Mount Diablo (fig. 6.24, 6.25). There are few distinct correlations between chaparral and geology (Bowerman 1944). However, the vegetation boundary is often quite clearly related to topography; as one GLO field note states: "Summit of hill… leave chamisal, enter oak timber" (Partridge 1873). GLO surveyor Ingalls (1868) specifies that his line south of Mount Diablo is a "very steep southern slope covered with chaparral." In addition, "chamisal ridge" is often-used phrase to describe the setting. Along some of the foothills, the southwest-facing slopes are replaced by grasses, while chaparral and woodland occupy the northeast-facing slopes. Chaparral does not occur exclusively in those areas, however. GLO surveyor Sherman Day (1853) describes his path south along the ranges southeast of Mount Diablo as "very precipitous on the W. side, and covered on that side with chamisal... avoiding entirely the high chamisal mountain." The rough and steep character of the land covered with brush was noted by GLO surveyors, who used phrases such as "broken and rocky with chemisal paths" to describe their lines (Dyer 1861). "Thick bushes" (Day 1853), "brushy ravines" (Thompson 1867), or "dense thicket" (Day 1853) and species such as Manzanita are recorded in some upland ravines, hollows, or drainages.

Thick and dense chaparral on ECCC hillsides posed an obstacle to GLO surveyors in the mid 1800s. Chaparral on steep slopes was not the landscape GLO surveyors enjoyed traversing and, in some places, was deemed "impassable." Field notes often contained phrases such as "North Boundary of the Section was not run on account of the thick chemisal brush which rendered it impracticable" (Thompson 1867) or "avoid thick 'chaparral' angle" (Ransom 1851). A touch of exasperation is detected in Tallyrand's 1872 survey: "I find it utterly impossible to run this first ½ mile of this line." One area in particular, the southeast part of Township 1N1E, was simply not surveyed and its general description was that the "hills become higher and are covered with brush" (Thompson 1865). GLO surveyor Wackenreuder (1875a) described the proportion of chaparral in the northern foothills: "half of it is overgrown with dense Chaparral, with scattering Oak and Pine trees; the other half yielding only scanty growth of grasses fit for sheep pasture." Not all the chaparral was dense; steep rocky slopes often only supported a sparse cover of brush (Cain and Walkling 2006). Hilgard (1881), in a general statement about the vegetation, comments that the "slopes and higher portion [of Mount Diablo] are mainly treeless and afford fine pasturage." As many surveyors appear to have surveyed through the brush as those who avoided it.

Based on the MCV alliance classifications from VTM attributes, mapped chaparral consists of 83.5% Chamise Chaparral, 7.4% Interior Live Oak Chaparral, and 3.2% Birchleaf Mountain-Mahogany (Sawyer et al. 2009). Bigberry Manzanita, Black Sage Scrub, California Sagebrush, California Sagebrush-Black Sage Scrub, and Toyon Alliances also occurred, each comprising 2% or less (table 6.3; 619 acres of the total 3,310 acres were mapped as chaparral from aerial photography, but not mapped by VTM, and were thus not included in this summary). The earlier mid 1800s data from GLO surveyors were less specific about brush species. Most surveyors appear to have used the terms chaparral and chamisal interchangeably, save for the detail-oriented Sherman Day, who included both chaparral and "chemisal" independently in his description of a line in the upper Kellogg Creek watershed. He also noted Manzanita bushes along some of his lines. Descriptions sometimes also mention scrubby oaks or oak brush.

In comparing historical chaparral boundaries mapped largely from 1930s data to 19th century GLO points noting brush, we found no consistent trend of expansion or contraction. Differences were observed among the datasets, but appeared related to error rather than directional change. For example, of 47 1930s-era chaparral polygons lying along survey lines, 24 were not noted by the GLO survey. On the other hand, of 69 GLO survey field notes concerning the presence of chaparral, 25 were not mapped in the 1930s.

A few of these comparisons did suggest change, where either a GLO point was showing the placement of a chaparral boundary that may have since receded, or

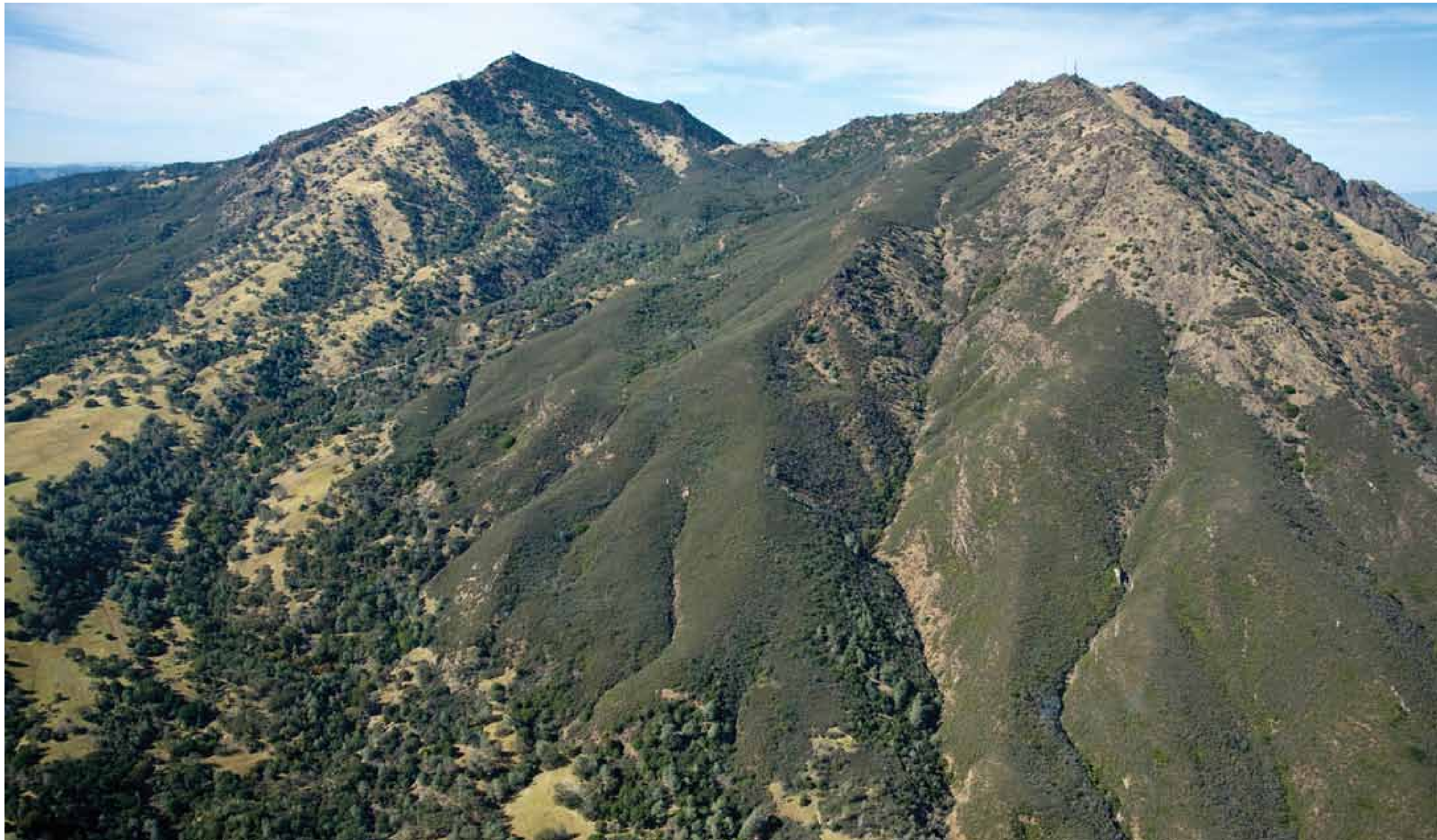


Figure 6.25. Chaparral on the slopes of Mount Diablo. Large swaths of chaparral mixing with woodlands are visible across the southern slopes of Mount Diablo (Photo October 24, 2009, by Scott Hein, www.heinphoto.com)

a mapped polygon was showing an area that was not chaparral at the time the surveyors went through. However, most of these inconsistencies are a reflection of the differences in how the vegetation was detected and interpreted as opposed to actual change. For instance, some of the polygons that were not included in the GLO data and vice versa were in the upper elevations, where GLO described “scrubby oaks” (Dyer 1861) and where tree and chaparral cover was likely mixed; these were areas that were difficult to classify using the aerial imagery. Another complicating factor is that many of the polygons not noted by GLO have boundaries that just barely cross over the line of the survey, which may not have been significant enough for the surveyors to note them.

Upon visually comparing the historical and contemporary aerial photography, we did not find extensive areas where the boundary of chaparral patches had changed dramatically between the two periods (1939 and 2005). A few chaparral boundary changes were detectable, but no distinguishable trend was found; suggestive evidence of both receding and expanding boundaries could be found for a few areas. It is unknown whether these areas faced different pressures (e.g. fire, grazing) or whether they reflect natural fluctuations in vegetation that occur at greater frequencies than the time elapsed between the two imagery dates. It is also unknown if any such shifts can be extrapolated back to the mid-1800s conditions. Two of the more distinguishable local shifts occurred along the south facing foothills in the Briones and Deer Creek valleys and are shown as examples in figure 6.26.

One of the more extensive areas of apparent change in the montane region is shown around the peak of Mount Diablo (fig. 6.27). While Jones & Stokes (2006) mapped the area as woodland and savanna, VTM data for the same area was assigned MCV classification of Mixed Chaparral and Grassland (Thorne pers. comm.), based on dominant cover recorded as chamise, Wedgeleaf Ceanothus, Black Sage, Interior Live Oak shrub and Mountain mahogany on the VTM maps. We therefore mapped this area as chaparral, although it is difficult to detect significant vegetation change in a visual comparison between the historical and contemporary imagery. Given that this may not be a true habitat type conversion, a modern classification of chaparral may be more appropriate here. Several GLO field notes from this area describe, “timber scattering oak, undergrowth chaparral” (Ingalls 1868), which supports the idea that the discrepancy is perhaps more a product of vegetation interpretation than actual vegetation change.

Visual comparison of historical and contemporary aerial imagery suggests that some chaparral areas have shifted in density as opposed to expanded or contracted (fig. 6.28). These changes were often slight, however, and hampered by challenging image interpretation due to factors affecting the comparability of the two datasets. In addition, it is unknown whether these perceived changes are simply due to natural local variability over time. Depending on location, we found some evidence for trends toward denser as well as sparser chaparral. Further analysis, using more quantitative imagery analysis methods and perhaps additional imagery from interim dates, is necessary to investigate whether there have been true shifts in chaparral density over the past 70 years and could begin to link these trends to factors such as grazing and fire.

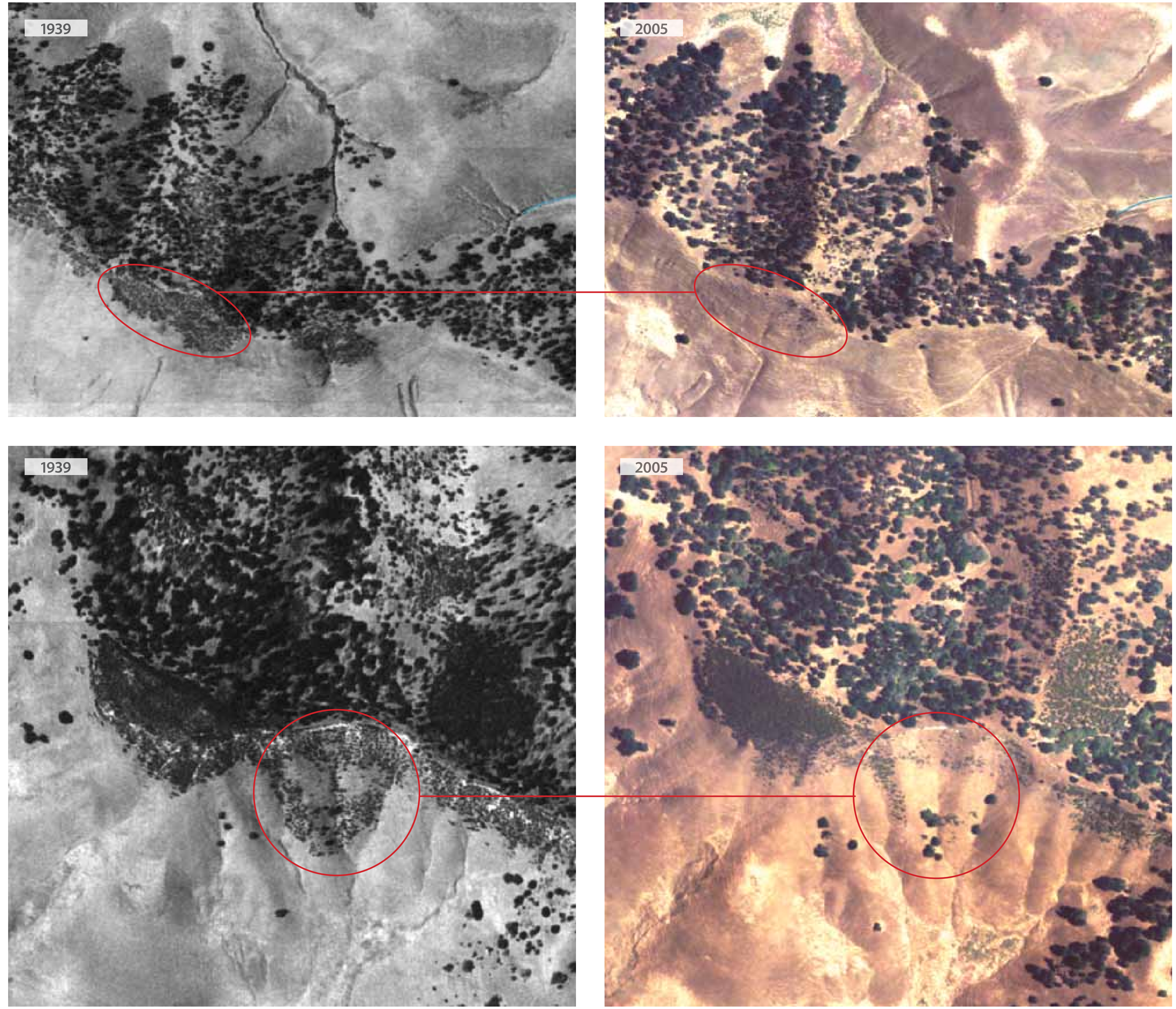


Figure 6.26. Changes in chaparral extent. The top set of historical and contemporary imagery shows a contraction of chaparral extent and density on the northern ridge’s south slope in the upper Briones Creek watershed. The second set of historical and contemporary imagery show a contraction of chaparral on the south slope of neighboring Deer Creek watershed. Such areas of evident 1939-2005 change are not common but are potentially locally significant. (Left: USDA 1939, courtesy of Contra Costa County and Earth Sciences & Map Library, UC Berkeley; Right: USDA 2005, courtesy of NAIP)

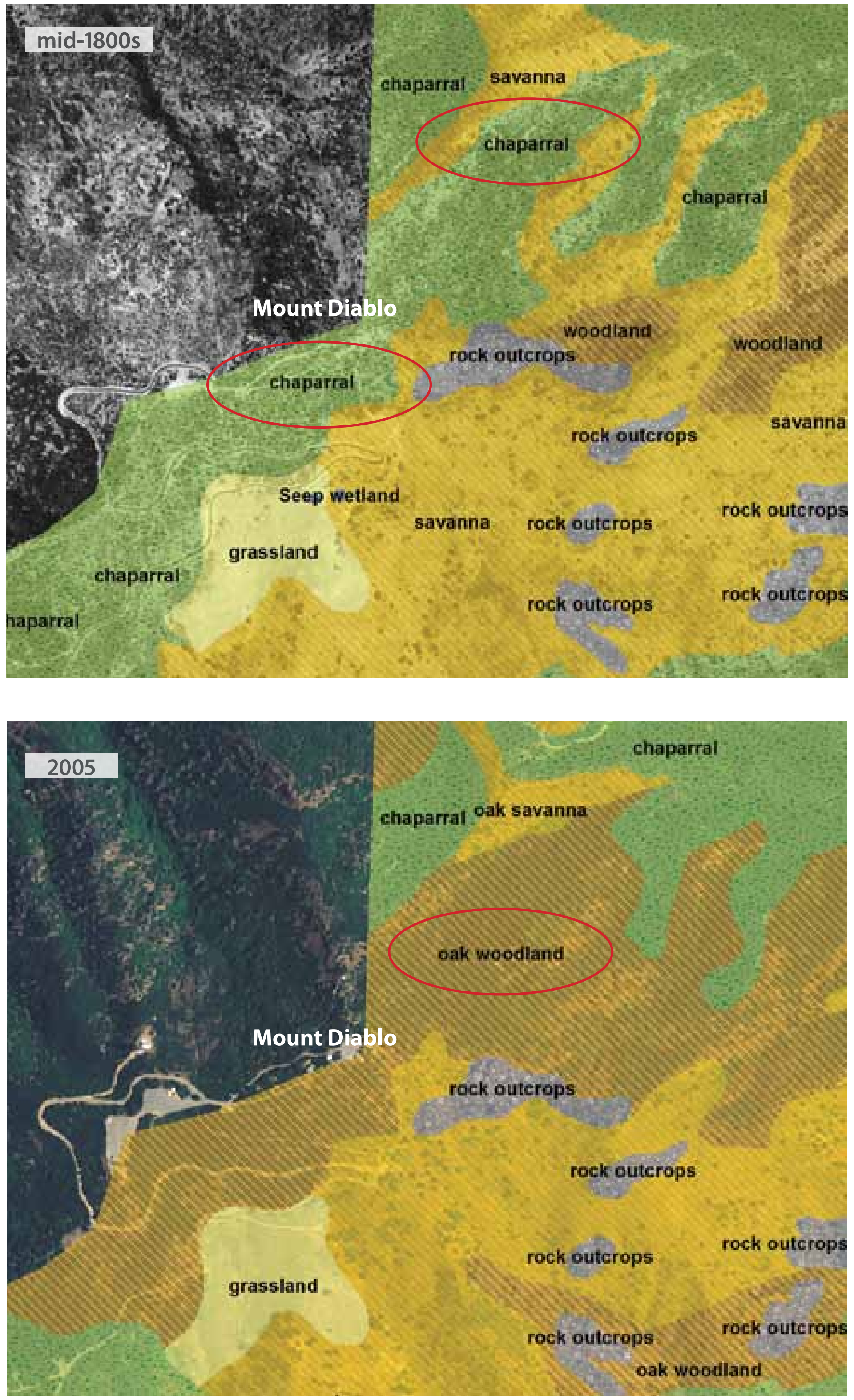


Figure 6.27. Apparent change on Mount Diablo: The area mapped as chaparral around the peak of Mount Diablo (top) from 1930s-era sources is mapped as woodland in the contemporary HCP mapping (bottom). This apparent change in vegetation community is likely a difference in classification and opposed to true habitat type conversion. Historical mapping was guided by chaparral species recorded by VTM, including scrub oak.

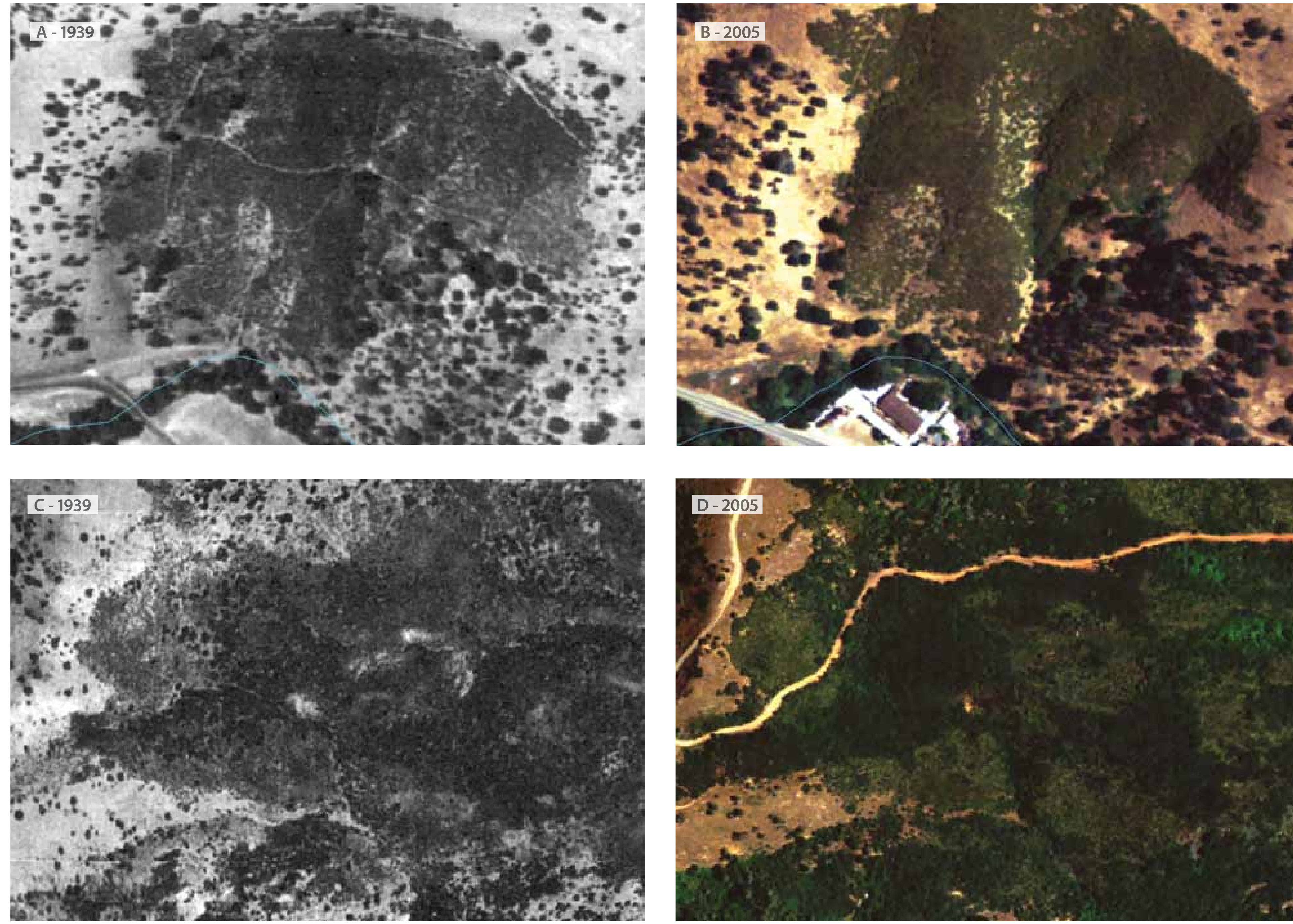


Figure 6.28. Changes in chaparral density. A, B) Chaparral appears to be somewhat less dense in the contemporary imagery in some parts of the patch, although the tonal differences in the black and white historical aerials are difficult to interpret. Also, the boundary seems to have contracted on the western side. C, D) As an example of a possible opposite trend, the few small open spaces within the chaparral apparent in the historical imagery have largely closed in by the time of the 2005 aerial imagery. Uncertainties in aerial interpretation do exist and it is also unknown whether these observed differences are simply localized natural flunctuations. (Left: USDA 1939, courtesy of CCC and Earth Sciences & Map Library, UC Berkeley; Right: USDA 2005, courtesy of NAIP)

The country is beautified by live oaks, where they have not been removed to make way for agriculture. The early settlers called this Eden Plains…East of Eden Plains, almost to Antioch, is a large tract of rolling, sandy, brushy country…It is a high, oak-dotted country…At yet it is a charming drive through this brushy, varied tract to Brentwood, especially when spring has spread the ground with a carpet of many colors, white, crimson, purple and yellow, in large continuous patches.

— CONTRA COSTA GAZETTE 1887

A young man was killed by one of them [a grizzly bear] in the dense forest of chamisal, three or four miles from Antioch. This chamisal is a short growth of underbrush, so dense as to be impenetrable by man, and covered about five thousand acres.

— CA. 1850 IN HULANISKI 1917

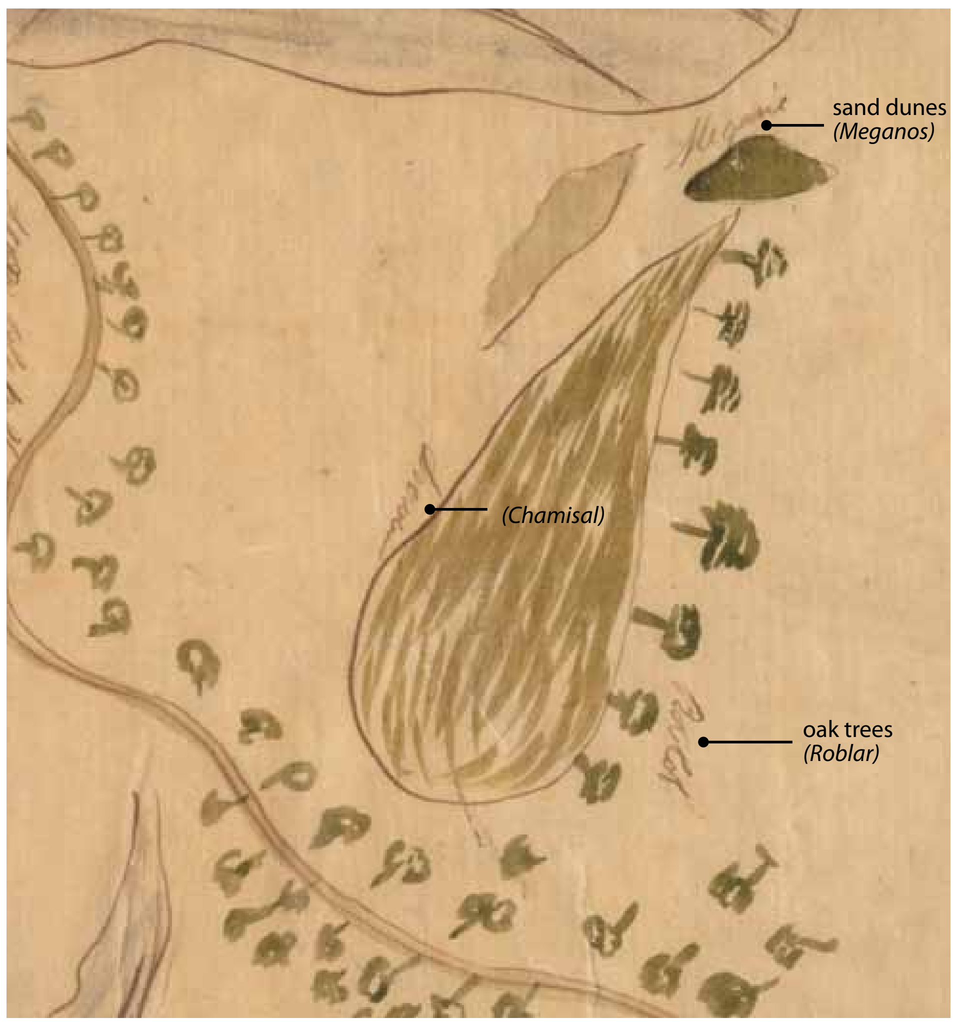


Figure 6.29. Interior dune habitats ca. 1840. This early map shows the chamisal, oaks, and dunes as major identifying features of ECCC. (U.S. District Court ca. 1840a. courtesy of The Bancroft Library, UC Berkeley)

Interior Dune Habitats

In the vicinity of present day Oakley lies a distinctive 6,800 acre area of sandy soils, remnant of eolian (wind-blown) processes during the Pleistocene. The sandy soils (termed Dehli or Oakley Sands) supported a dense 2,800 acre patch of scrub vegetation and scrubby live oaks, surrounded by a more sparsely-vegetated dune habitat covering an estimated 5,600 acres (fig. 6.29). Regional maps depicting Contra Costa in the 19th century often show the scrub patch, or "chamisal" as the defining feature of the area (Britton and Ray 1871, Whitney 1873, Hall 1887), and an early surveyor described "about 6000 acres of brushwood and sandy land" (Wolfe n.d.). The almost complete destruction of this dune habitat type is one of the largest changes to ECCC.

To depict this feature in the historical map, we defined two types of dune habitat - interior dune scrub and interior dune (vegetation undefined). Interior dune scrub (also known as inland dune scrub; CALFED 2000a, b) has been used to describe the Antioch Dunes by a number of recent sources (Holland 1986, Bettelheim and Thayer 2006, Thayer 2010). We further refined this class to distinguish the dense, scrub area from the more sparsely vegetated surrounding area. We mapped the dense portion as interior dune scrub, while the surrounding area (including the Antioch Dunes) is mapped as a more general interior dune type (interior dune, veg. undef.). These areas were historically vegetated, but we have less direct data about the vegetation cover and boundaries, so this class represents the likely range from live oak savanna to sparse scrub to herbaceous cover (fig. 6.30).

Together, these dune habitats historically supported a number of species. The most well documented are silver bush lupine (*Lupinus albifrons*) and live oaks (*Quercus agrifolia*). It was described as "a patch of considerable extent of chaparral and scrub oak" (History of Contra Costa County 1882). Today the most intact remnant, the Antioch Dunes, supports three rare species: Antioch Dunes evening primrose *(Oenothera deltoides spp. howellii),* Contra Costa wallflower (*Erysimum capitatum angustatum*), and Lange's metalmark butterfly *(Apodemia mormo langei),* for which the Antioch Dunes preserve was created (CNDDB, HCP). Silvery legless lizard (*Anniella pulchra pulchra*) is also found here and has been recorded since the 1940s (Miller 1940, Bettelheim and Thayer 2006). The far-flung patches of dune habitat today support herbaceous species such as *Croton californicus*, *Eriogonum gracile*, and *Lessingia gladulifera* (Thayer pers. comm.).

The patch of dense interior dune scrub covered much of Oakley, extending 1.8 by 3.8 miles at its widest point (the area roughly between the intersection of Highway 4 and Delta Road and the junction of 4 and 160). GLO surveyors from the 1850s to the 1870s described encountering a giant patch of "impenetrable chamisal" (Dyer 1962b) in the vicinity of Oakley that forced them to interrupt their survey and divert their lines "west to avoid thick brush" (Ransom 1851). Surveyors clearly noted entering and exiting the patch of "dense chemisal" and "high chamisal" (Dyer 1862b, Wackenreuder 1875b). (The term "chamisal" or "chemisal" as used here refers more generally to the impenetrable nature of the scrub rather than to the shrub species chamise (*Adenostoma fasciculatum*) (Brown 2005, Beller et al. 2010).) Based on the

Figure 6.30. Remnant oaks and sand deposits in1939. Remnant sand patches create the light mottled pattern visible in this photograph, and contrast with the dark clusters of live oaks still present in areas that are not cultivated. (USDA 1939, courtesy of Contra Costa County and Earth Sciences & Map Library, UC Berkeley)

shape outlined by these notes and the accompanying map (Dyer & Wackenreuder 1862/1875), we estimate the scrub patch at approximately 2,800 acres. Maps and descriptions from the late 19th century show the scrub with slight variations in size and shape, ranging up to 5,000 acres in area (Hulaniski 1917).

This "forest of chamisal" was seen as worthless for agriculture because of the sandiness of its soil (Smith 1866, Hulaniski 1917). Little effort was made to clear the Oakley chamisal until the 1880s, when James O'Hara began clearing the brush and planting almond orchards. A local historian described that O'Hara "broke the heavy growth with a roller," burned the "grubby trees and chaparral," then used horses to "bring up all the shrub and tree roots which were gathered and burned" (Benyo 1972: 116-7). O'Hara slowly expanded outward, buying the land cheaply, clearing it to plant, and then reselling to others at a higher price. The California Agricultural Experiment Station stated that the almond trees "yield enormously, but the trees make very little growth; the sand is loose enough to drift when plowed" (Hilgard

1891). Once begun, the transformation of the Oakley Sands to agricultural land was rapid. In 1916 Oakley was advertised as "home of fruits, grapes, and almonds" *(Byron Times* 1916b). By 1939 (as visible in aerial photography) only tiny remnant clumps of scrub remain, and almost the entire historical extent had been covered with orchards and vineyards.

Surrounding the dense scrublands was a 5,600 acre expanse of scattered stands of live oaks and scrub (fig. 6.31). Although the Antioch Dunes were the most mounded portion of this interior dune habitat, GLO surveyors also documented a ridge along the southwest side of the dense interior dune scrub. Oaks were a notable part of this habitat. Surveyor Wackenreuder described "land, half covered with chemisal; balance with live oak timber. Soil, poor and sandy" (1875b). Descriptions repeatedly note the presence of both oaks and scrub: "grubby trees and chaparral," "short growth of underbrush," "chaparrelle and live oaks" (Metcalfe 1902, Hulaniski 1917, Benyo 1972). Contemporary species accounts indicate the presence of silver bush lupine (Bartosh pers. comm., Thayer pers. comm.). GLO surveyors emerging from the central patch of chamisal described entering "scattering oak timber" (Wackenreuder 1875b) extending north and east to the edge of the Oakley Sands, and recorded thirteen different live oaks as bearing trees. These trees were the only live oaks recorded within the plains geomorphic unit of ECCC (see fig. 6.17). The early *diseño* map labels this area as a *roblar* (U.S. District Court, Northern District ca.1840a; see fig 6.29). Although *roblar* is typically used to refer to valley oak woodlands and savannas (Minnich 2008), the GLO surveyors and other textual evidence suggest that the most accurate translation in this case is simply "oak woodland." Some quotes indicate that some of the oaks may have been large: the *Byron Times* in 1916(b) described that near Oakley "a dozen years ago the entire country was covered with giant oaks." In 1931 Jepson recorded "sandy field, scattered live oaks…*Quercus agrifolia* [coast live oak] I found about Oakley on the sandy flats at about 50 or 60 feet." Although some of the oaks were scrubby, others were large and well-developed. GLO tree data supports a range of sizes – the recorded trees range in size from 3 to 60 inches in diameter.

The interior dune habitat also historically extended in patches west along the Antioch-Pittsburg shoreline. Oaks occupied several larger sand deposits identified in modern geology maps, as well as smaller, previously unidentified deposits. The longest-surviving local oak groves were documented on the West Antioch shoreline in the vicinity of the Babe Ruth Baseball Field (Somersville Road). Trees were documented independently by maps (Davidson 1887, San Pablo-Tulare Railroad n.d.), oblique photography (Russell ca. 1925), and land grant testimony (Smith 1866). An early landowner stated explicitly that there "used to be quite a bunch" of oaks "standing in the Tule" and associated those trees with a "small mound of sand" (Smith 1866). The larger grove mapped west of Antioch also corresponds with an isolated deposit of eolian sand mapped by Atwater (1982). It is likely that the smaller groves nearby were associated with unmapped exposed portions of this formation within the surrounding alluvial deposits. We used this evidence to map several small patches of dune habitat on the sand deposits.

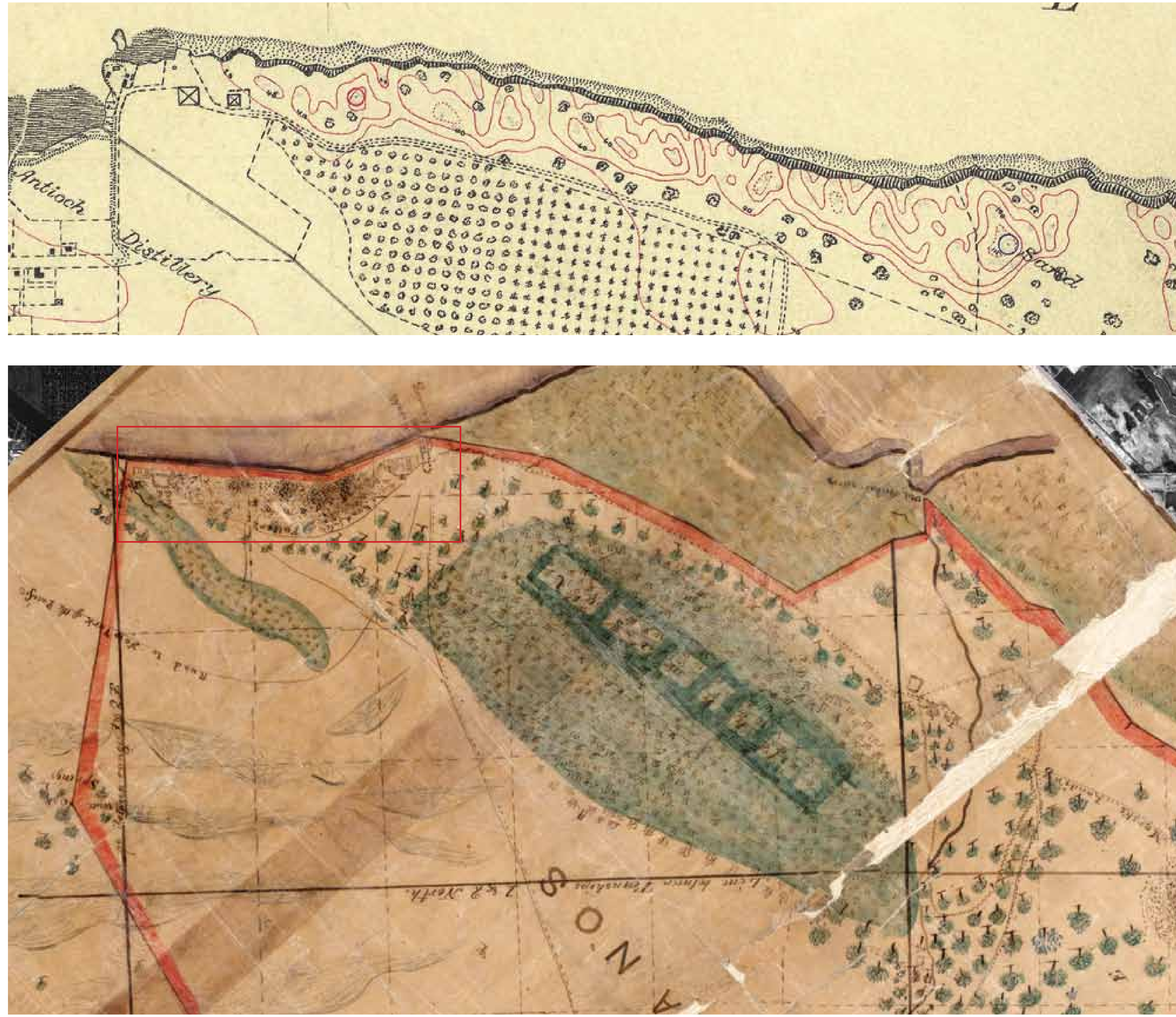


Figure 6.31. Savanna along the ECCC plains. (top) Individual oaks in the Antioch sand dunes are shown on US Coast and Geodetic Survey map in 1887. To the south of the dunes, an orchard has been planted across an area shown as oaks on the earlier map. (bottom) A live oak savanna (green tree symbols) surrounding the Oakley interior dune scrub (large green hatched area in center) to the north and east is depicted on an 1853 land grant map. Marsh Creek flows to the tidal marsh to the right of the scrub patch. The dark green boxes in the scrub surround letters spelling "chamisal." At the top right of this image, the area in the red box represents the Antioch Dunes, shown in detail in the top image. (Top: Davidson 1887, courtesy of NOAA; Bottom: Whitcher 1853a, courtesy of The Bancroft Library, UC Berkeley

To the east, patches of Oakley Sands extended well into the tidal wetlands and were mapped as far northeast as Bradford and Webb Tract, as well as south towards Point of Timber (fig. 6.32). Within the tidal marsh, sand mounds rose above the marsh plain as shown on topographic maps (USGS 1913 (Woodward Island)). These dunes formed prior to the development of the tidal wetlands in the Delta, and ranged from less than an acre to 25 acres in size (Atwater 1982). Although little is known about the vegetation of these sand mounds, some remnants support live oaks today. Others were likely covered with grasses and other dune scrub vegetation (Bartosh pers. comm., Thayer pers. comm.).

We include the Antioch Dunes as a subset of the interior dune habitat type, as they appear to have supported a mix of oaks and scrub, similar to the surrounding interior dunes (see fig. 6.31). Portions of the Antioch Dunes were bare, intermixed with live oak and scrub. The oaks in this region were well-documented. An oak-dotted stretch of riverbank along the dunes became popular with bathers such that it was known as "Oak Grove Beach" (Hohlmayer 1991). Towards the eastern edge of the dunes, towards present Antioch Bridge, explorer Anza described camping near "a green grove of live oaks and oaks" (Brown 1998). The early coast survey map depict trees growing along the sand ridges (Davidson 1887), and early maps show the Antioch Dunes as a distinct feature due to their height. The dunes were one of the notable natural features of ECCC (U.S. District Court, Northern District ca.1940a; Whitcher 1853a). Both Los Medanos and Los Meganos land grants take their names from the dunes.

To determine the boundary of the Antioch Dunes we used a combination of the 1887 T-sheet and detailed 1916 USGS map (Collinsville). Historically, we estimate that these dunes covered approximately 120 acres. Our estimate is smaller than some other estimates (e.g., Howard and Arnold 1980), but we find that the high mounded dunes were only a narrow strip along the river. Botanist Burtt-Davy described the dunes in 1895:

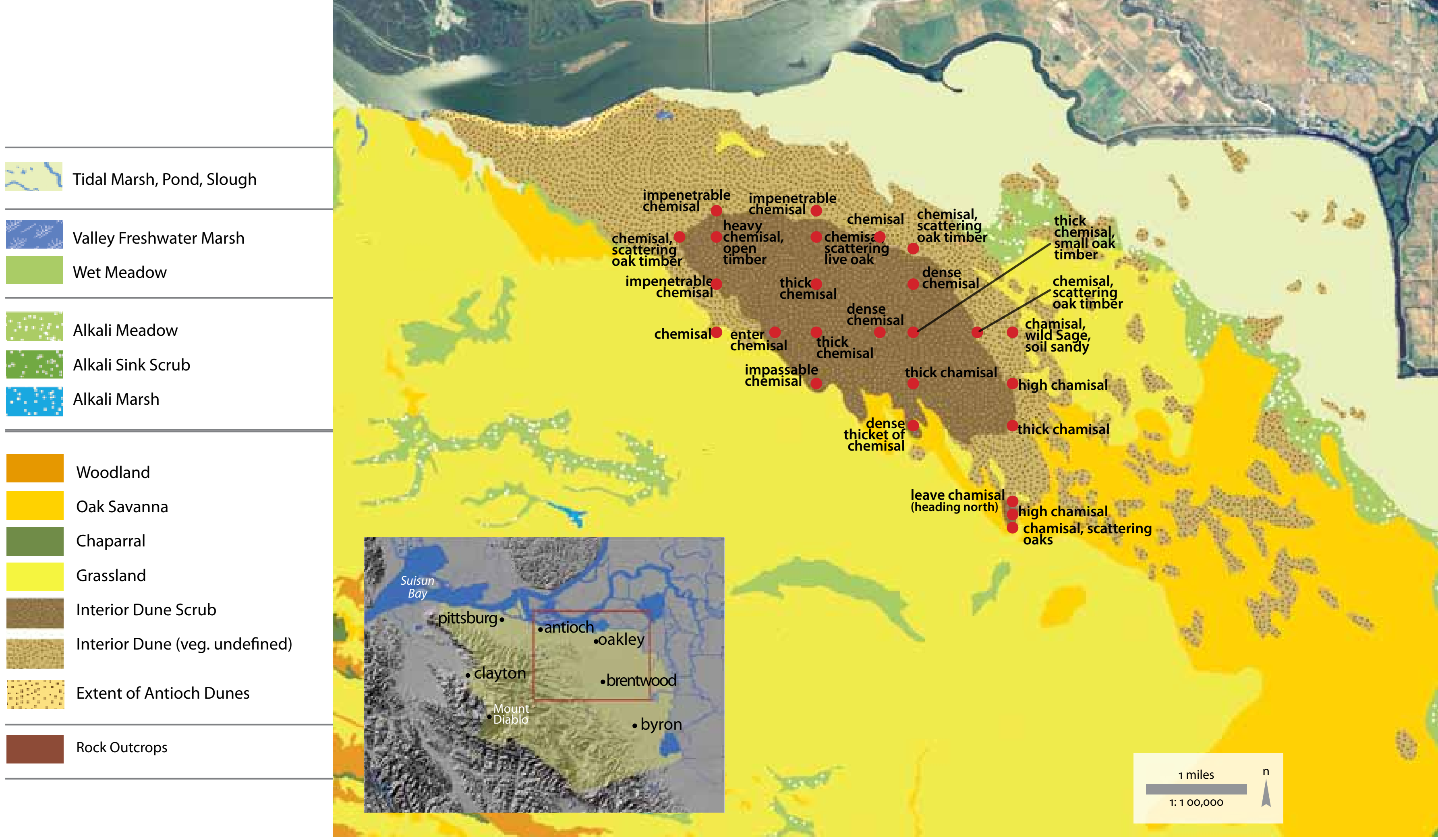
> A natural levee of sand some 150-200 (?) feet in height borders the river for several miles south *[sic]* of Antioch and produces a flora akin to that of the southern San Joaquin Valley, very different from that of *[the]* rest of the surrounding country. At this time these sand-hills are brilliant with flowers and, being left uncultivated, form fine botanizing ground: besides herbaceous plants there are oaks and shrubby Lupines. (Burtt-Davy 1895 in Howard and Arnold 1980:3)

The Antioch Dunes were mined heavily beginning in the 1880s to produce bricks and asphalt, significantly lowering and smoothing them (Davis 1958). The 120 foot height shown by USGS and the T-sheets may significantly underestimate their historical height. One early surveyor described the *meganos* or dunes "in some places 100 or 200 ft high and covered with brush" (Wolfe n.d.). Today the area within the refuge reaches only 50 feet above river level.

Only small, fragmented patches of dune vegetation remain today, and the dense Oakley interior dune scrub has entirely disappeared. However, the Antioch Dunes, the most intact remnant, have been substantially protected, and small additional patches of sands and live oaks remain scattered across Oakley (fig. 6.33).

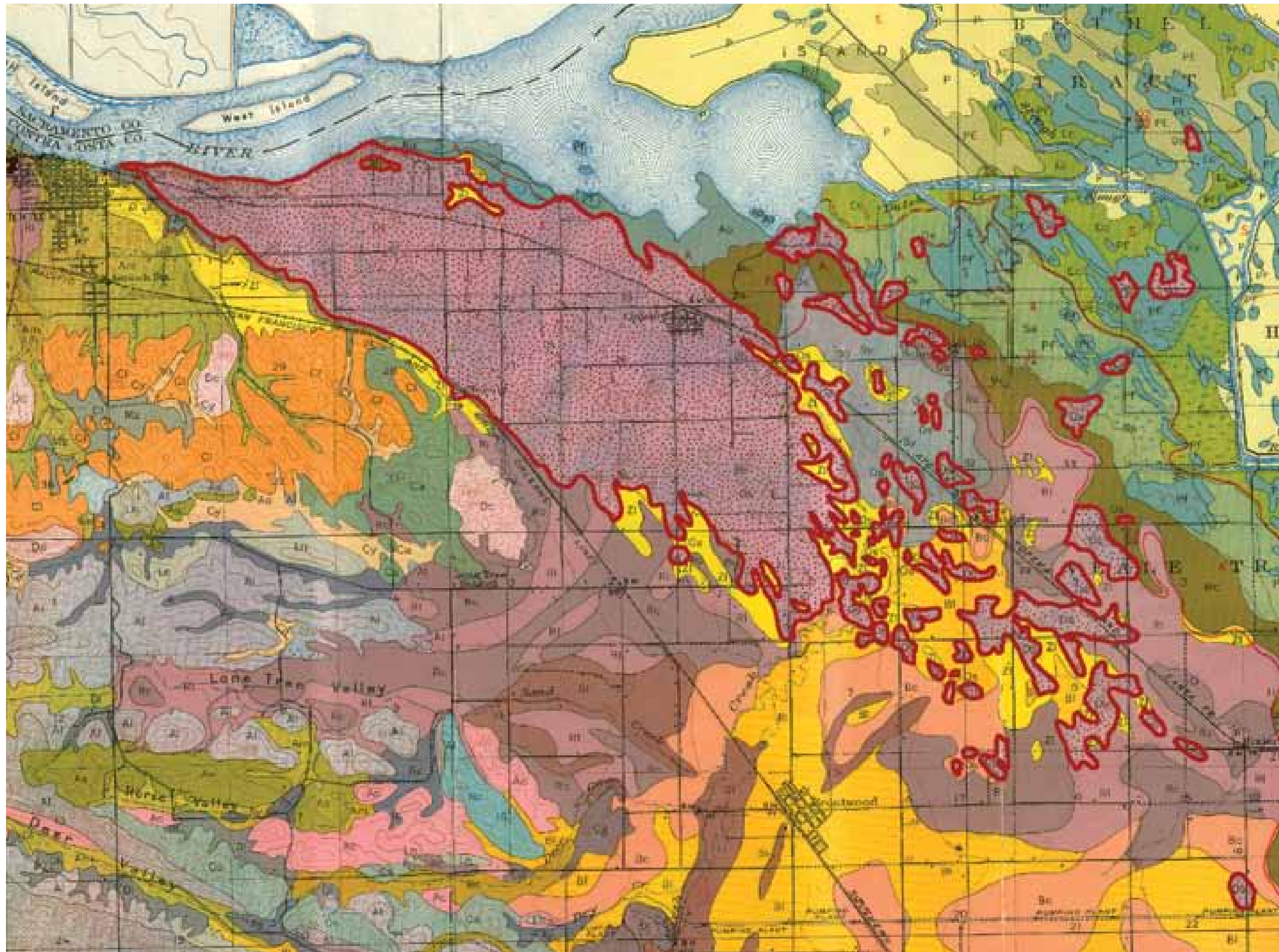
Figure 6.32. Oakley sands and interior dune scrub. (right) At top, GLO quotes (1851-1872) indicating dense brush are displayed together with the historical habitat map. The extent of the Antioch Dunes is indicated, as shown in the legend. At bottom, the 1933 soil survey of the surrounding area is displayed. The large patch of "chemisal" fits within the area of Oakley sand (Os, purple), outlined here in red. Note the patches of purple Oakley sand continuing to the south and east. (Bottom: Carpenter and Cosby 1933)

Figure 6.33. Antioch dunes evening primrose. (below) The Antioch Dunes appear to have supported some species not found elsewhere in the interior dunes. This image was taken at the Antioch Dunes National Wildlife Refuge. (October 1, 2009, by Ruth Askevold)



The medano [dune] is a conspicuous and unmistakable natural object.

— JOHN MARSH 1865



DISCUSSION

Changes in historical dryland vegetation in East Contra Costa County (ECCC) are complex and heterogeneous. We found evidence for dramatic large scale landscape changes in the plains, including the loss of thousands of acres of savanna and interior dune scrub (fig. 6.34) that have not been well documented previously. On the other hand, changes in the montane and foothill regions are more subtle. Chaparral patches in the foothills and montane regions were historically relatively small and appear to have decreased in extent by several hundred acres overall in the past 70 years (fig. 6.35). In these same upper elevation regions, savanna and woodland distribution have also decreased in extent, though not dramatically (fig. 6.36). However, these habitats may be subject to longer term trends, due to the long-lived nature of the species, and within-habitat type shifts. For example, visual comparison and preliminary analysis suggests there may be trends in age class structure.

Vegetation Patterns and Local Land Use History

Within the montane and foothill regions, we found that available mid-1800s sources tended to corroborate the general distribution of habitat types represented in the 1930s-era habitat map, though generally without sufficient spatial resolution to evaluate localized changes, particularly due to heavy woodcutting that occurred in many areas in the late 1800s. We therefore consider that the mapping in these upper elevation areas represents a minimum mid-1800s distribution of oak woodlands, as it is likely that some areas shifted from woodland to savanna and savanna to grassland in the later decades of 19th century.

Evidence from the GLO dataset supports the general distribution and abundance of habitat types that are represented in the historical habitat map. For example, where bearing trees are found, our mapping usually shows either savanna or woodland. However, this data is not resolved at the level to detect localized shifts between woodland and savanna boundaries. Most GLO surveys were performed in the late 1850s and 1860s, at the onset of rapid settlement, mining, and the wheat boom of the late 1860s, which prompted the clearing of some areas. Although grazing and the absence of native fire management practices was a factor for several decades prior to the survey, substantial resulting changes to vegetation patterns such as tree distribution are unlikely to have taken place by that time. This interpretation is supported by Cook (1957), who makes the "tentative" conclusion that in the Bay Area "the distribution of vegetation in 1775 was substantially the same as described by the American settlers of 1850 and thereafter and allowing for the devastating influence of white man, more or less as it is today." For example, while oak recruitment may have been affected by this time, it is likely that the established oaks of the GLO survey largely reflect their historic distribution because they had yet to face wholesale clearing pressures.

The montane, foothills, and plains regions have vastly different land use histories, which are reflected in the current distribution and extent of historical dryland habitats. Evidence suggests that oak woodlands, savannas, and dune habitats have been dramatically reduced in extent across the plains. The plains region faced early and widespread modification. In 1862, one GLO surveyor noted that cutting had already occurred. He described the area as being "at one time covered with a heavy growth of oak timber but most of it has been cut down. A few of the limbs cut for wood and the rest are now rotting on the ground" (Dyer 1862a, referring to T1N R3E). Other evidence records oaks being cut for fuel in Clayton Valley ca. 1850, although such practices could have extended into the plains within the study area as well (Gehringer n.d.). This early cutting and a general paucity of many spatially explicit mid-1800s sources suggests the possibility that the historical extent of savanna and woodland on the alluvial plains and perhaps in the foothills is undermapped.

Dry farming of wheat may have had an especially significant impact on blue oaks and valley oaks within this region in the later decades of the 1800s (Adams pers. comm.). This occurred in the plains as well as along the foothill region, as often described in early histories of the county: "In the valleys and on the sloping foothills grain is grown in large quantities" (History of Contra Costa County 1882; see p. 16). Disking was practiced in some areas to improve rangeland for cattle or for dry farming (Jones & Stokes 2006). One example of this is Round Valley, where plowed land is visible in the 1939 aerial photography and GLO bearing trees suggest that trees may have been more numerous prior to cultivation (Adams pers. comm.).

Cultivation of the montane region of ECCC has occurred only in localized areas, although cattle ranching was well established across the area by the mid-1800s. Large numbers of trees were undoubtedly removed in the immediate vicinity of settlements and mines and used as fuel and for fence posts. The predominant land uses within ECCC into the late 1860s were livestock grazing and the production of hay and grain, which likely did not directly conflict with the presence of oaks initially (Jepson 1910, Bartlett 1928). However, trees were likely thinned; even through the mid-20th century, ranchers thinned hillside woodlands but left larger trees in place because they were too much work to fell (Engelhart pers. comm.).

Within the upper elevation regions, the extent and distribution of habitats in the ECCC dryland vegetation did not alter dramatically over the last 70 years and may not be substantially different from the mid-1800s picture. However, changes within habitat types may be significant (e.g., localized losses of individual trees, changes in density). More subtle shifts in vegetation type distribution and density have likely occurred in response to factors such as altered fire disturbance regimes, grazing and rodent pressures, and herbaceous understory community changes (Griffin 1977, Borchert et al. 1989, Davis et al. 2011). These trends may have contributed to some of the localized increases in density within some upper elevation montane woodlands and chaparral as well as decreases in some oak woodlands and savannas. However, our analysis did not find conclusive evidence of wholesale community shifts or large vegetation boundary changes. These boundaries may resist large-scale shifting due to physical controls. For example, one possible reason that chaparral boundaries have remained fairly stable could be because of strong topographic and edaphic controls (Edwards pers. comm).

Figure 6.34. Valley oak in "Valley de los Poblanos at the south end of Rancho." This oak is likely a remnant of the historical valley oak savanna near the confluence of Briones and Marsh Creek near the present day location of the Marsh Creek Reservoir. (Unknown n.d., courtesy of East Contra Costa Historical Society)

Figure 6.35. Vegetation in presentday Black Diamond Mines Regional Preserve. This photograph was taken as part of the Wieslander VTM project and a member of the mapping team can be seen roughly in the center of the image. Its caption reads: "1/2 mile south of Somerville. *Arctostaphylos andersonii auriculata* [Mount Diablo manzanita] on a rocky bluff where it ranges from 3 to 5 ft in height. Note *Pinus coulteri* [Coulter pine] and *sabiniana* [California foothill pine]." (Wieslander 1935b)

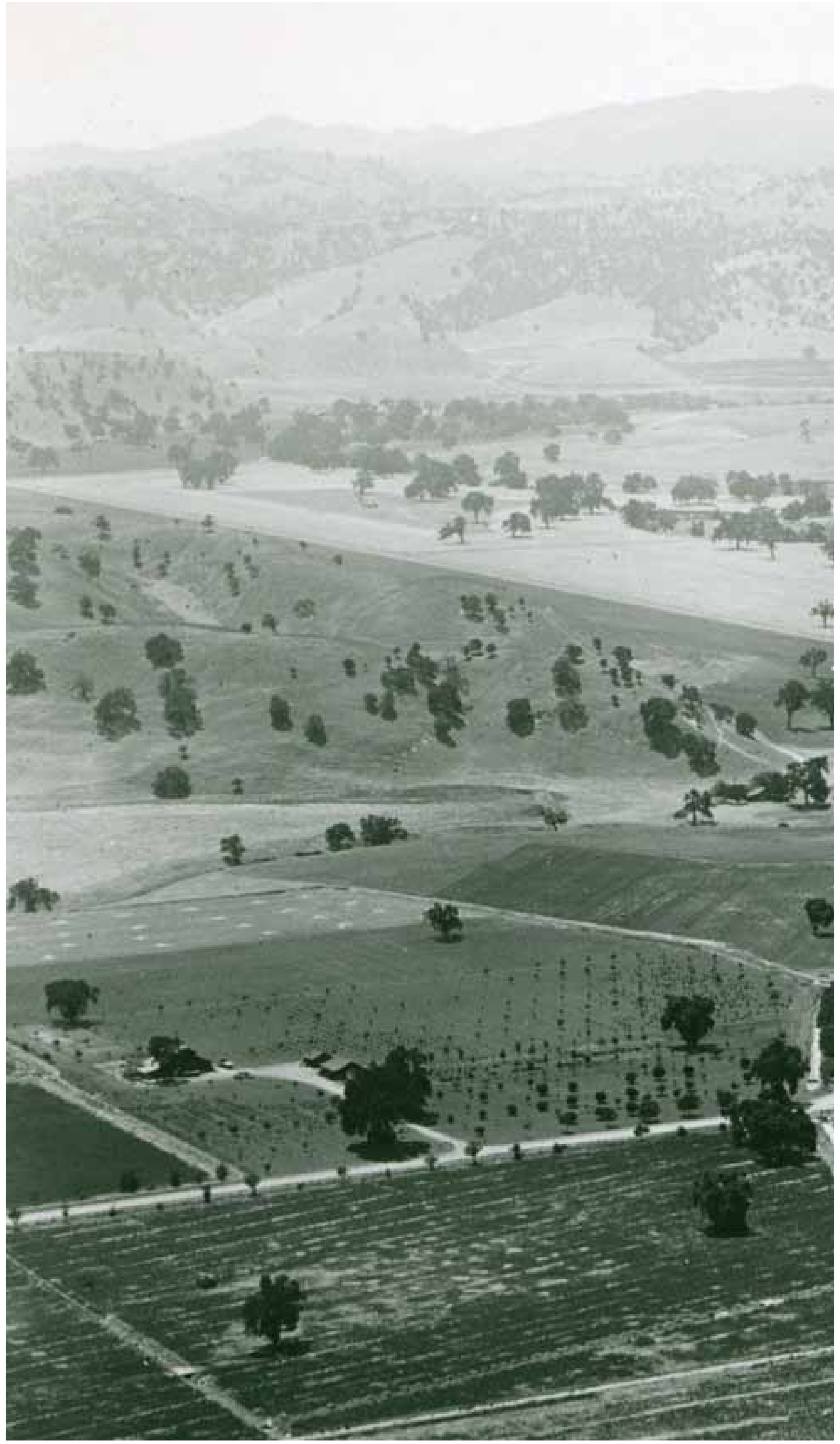


Figure 6.36. Mixed foothill land cover. This image shows a patchwork of agriculture, grassland, and scattered oaks, as foothills transition to plains. Marsh Creek Road is visible in the foreground, heading west to cross Marsh Creek just to the right of the image. Further upstream, riparian cover along Marsh Creek as it exits the foothills is visible in the background. This image is part of a series that includes the image in figure 6.15. (Russell ca. 1925, courtesy of the State Lands Commission)

In some locations, apparent trends toward a denser tree cover seem to be attributable to larger tree canopy sizes. This would suggest that size class distribution has changed over the course of recent history. This can be attributable, in part, to the early loss of older trees to wood cutting and the absence of young trees due to low recruitment rates. Such trends have been studied in second growth stands of blue oak that appear to have been established as a result of land use changes in the 1860s. For example, a study on Tejon Ranch in southern San Joaquin Valley concluded that second growth regeneration was due to the combined effect of severe drought and heavy grazing pressure in the early 1860s (Mensing 1992). In another study, Swiecki and Bernhardt (1993) found that a stand of blue oaks at one site in the northern part of Mount Diablo State Park was of the same age class due to early cutting. This observation is supported by a study by McClaran (1986), who concluded that 70% to 85% of blue oaks in California were from "stump sprouts." While overall extent of woodland and savanna habitat appears to have been relatively stable in recent history, present findings reiterate concerns about the long-term future of blue oak woodlands, which have been identified as a threatened habitat due to lack of regeneration (Allen-Diaz et al. 2007).

Indigenous management of California vegetation has received significant attention in recent years (e.g., Stewart et al. 2002, Anderson 2005). Specific understanding about how vegetation patterns were affected in particular areas, however, is generally not available. Indigenous populations along the Coast Ranges may have averaged relatively high densities of 1-3 persons/km^2 (Keeley 2002, Allen-Diaz et al. 2007). Native peoples routinely burned in coastal and foothill landscapes, a practice that would have promoted grasslands over shrublands (Keeley 2005) and maintained open understories in savannas (Anderson 2005), but may have had only small effects on oak establishment and early growth, depending on the fire temperatures (Bartolome et al. 2002, Tyler et al. 2006, Allen-Diaz et al. 2007).

Although the fire frequency under native management is relatively unknown in ECCC and the East Bay hills, some researchers have proposed that fires due to both natural and anthropogenic ignitions occurred every 5-15 years (D'Antonio et al. 2000). Relatively high burning frequency is supported by one account of the Mount Diablo area, which stated that "in the fall season… the Indians sometimes set large portions of the surface of the mountains on fire" (Olmstead 1962). In the absence of fire, we would expect to see a trend toward higher proportions of chaparral over the last 150 as the fire regime has been suppressed. This is under the assumption that fire played a role in keeping open areas of grassland that would have otherwise been replaced by a different climax community (McBride and Heady 1968, Mensing 1998). The relationship of fire to oak regeneration is less established, and depends largely on the fire frequency and intensity (Griffin 1977, Bartolome et al. 2002).

Fire regime changes over the historical period further complicate our ability to understand trends in the habitat distribution. After the cessation of native management in the early 1800s, fire frequency on Mount Diablo increased in the late 1800s and early 1900s as more tourists and activity caused an increase in human-caused fires. Frequency has since decreased as a result of fire suppression practices (Adams pers. comm.). It is not well understood how these frequencies compare to those of the native management period. Furthermore, some researchers have suggested that, while the structure and composition of the landscape encountered by Spanish explorers was likely modified by indigenous land management, subsequent Euro-American land use practices, such as grazing, may have replaced and, in some cases, exacerbated effects of the indigenous fire regime (Keeley 2002). It is also important to remember, when considering land management practices, that factors are interwoven. That is, even if one were to replicate native fire management practices, it is unlikely that it would have the same effect on the landscape that it once did, given the introduction of non-native and invasive species as well as the different land uses of today.

The fire record compiled by Mount Diablo State Park includes nine fires prior to 1930 (Shafer pers. comm.). The first fire on record occurred in 1891 on the east side of the mountain. The summit area of Mount Diablo was again burned in 1922. The largest fire in the record occurred in 1931 on 25,000 acres and started at Marsh Creek Road. Given that this large fire occurred within a decade of the Wieslander VTM project and the 1939 aerial photography, interpretations of the vegetation should consider that disturbance, in that it may affect the density and type of vegetation observed. For instance, in those burned areas chaparral may be thinner in the historical aerial photography compared to the same area today, given the more recent period of fire suppression (Nielson pers. comm.). Some find that chaparral today that hasn't been burned within the last several decades is, in many places, in the process of succession to oak woodland (Adams pers. comm., Shafer pers. comm.). The few years' time lapse between the VTM project and the historical aerials could be significant following such a substantial disturbance.

Along with the changing fire regime, grazing potentially had a wide influence on the landscape (see p. 67). In 1859, one writer stated that "stock may be seen grazing in all directions on the mountains" (Olmstead 1962). Swiecki and Bernhardt (1993) found that grazed areas had few saplings, supporting concerns about the effect of grazing on blue oak regeneration. Others have also found that browsing negatively impacts regeneration (Bartolome et al. 2002, Davis et al. 2011). However, the absence of grazing does not always translate to successful recruitment (Ertter and Bowerman 2002). Many scientists have shown the importance of grazing for oak establishment as grazing reduces the non-native grasses which can outcompete young tree for moisture (Jones & Stokes 2006, Allen-Diaz et al. 2007, Edwards pers. comm.).

Our mapping does not suggest, however, that significant changes in the extent of chaparral have taken place as a result of fire and grazing, although chaparral density may be affected. Chaparral extent in the upper elevation areas of ECCC does not appear to have altered significantly over the past 150 years, suggesting that there has been no substantial change in potential habitat for species of concern such as the Alameda whipsnake in this part of the study area.

Grasslands have also potentially been affected by fire and grazing pressures. However, more significant changes in the composition of native perennial bunchgrasses and annual forbs have been wrought by the early invasion of exotic annuals. The impact of these invasives has caused native grasslands to become one of the more threatened ecosystems in California (Holmes 1990, D'Antonio et al. 2000). Such invasions may have been fostered by increased grazing and fire suppression. For example, local changes in grazing regimes have demonstrated an increase in native grasses (as well as invasives) under reduced grazing conditions. Crop agriculture is also suggested to have been a significant factor in the decline of native grasses (Stromberg and Griffin 1996, D'Antonio et al. 2000). Although the invasion of grasslands by woody vegetation such as chaparral is well documented elsewhere in the western United States (Keeley 2005), we found relatively little evidence of such a trend over the period examined. As discussed, density of chaparral and woodlands has certainly increased in some locations, but most loss of grassland is attributable to development and cultivation pressures. This suggests that the loss of habitat for species of concern such as kit fox has occurred primarily due to urban and agricultural expansion, as opposed to the indirect effects of vegetation type conversion as a result of fire and grazing.

Implications for Restoration

While many of the former valley and blue oak savannas are now intensively developed as urban areas or reservoirs, there is some potential for oak savanna restoration in the smaller alluvial valleys, such as Cowell Ranch, Round Valley, and Los Vaqueros and valleys east of Black Diamond (Adams pers. comm.). These areas have likely undergone transformations similar to the area along Marsh Creek just above the reservoir, which was occupied by oak savanna in 1939. Today it is covered with grassland and some agriculture, with some remaining scattered oaks. Restoration of these habitats in relatively undeveloped areas could help reestablish this underrepresented vegetation type. Additionally, local factors affecting tree establishment, such as grazing pressures and groundwater availability, would be important to consider.

Re-establishment of some of the functions of oak savanna could also be achieved by integrating oaks within developed landscapes. While this would not support all of the functions of oak savanna, well-designed oak planting strategy could offer significant ecological benefits (Whipple et al. 2011). Trees were widely spaced historically in areas such as Point of Timber and perhaps across much of the plains oak savanna. Re-establishment of widely-spaced oaks within the contemporary urban environment may be able to approximate this historical distribution. However, due to changing conditions and particularly changes in groundwater levels due to Marsh Creek Reservoir and irrigation of the eastern margin of ECCC, historical oak savanna habitats might no longer support oaks. Further investigation of contemporary conditions would be needed.

Restoration strategies could also seek to reintroduce some of the historical diversity of oak woodlands and savannas. Although blue oak woodlands still persist throughout much of ECCC, oaks exist in a much narrower setting than they once did. Historically, there were blue and valley oak savannas, oaks associated with sand hills and dunes, and giant valley (presumably) oaks in the vicinity of Point of Timber. Although the large interior dune habitats and associated live oaks near Oakley have largely been covered with development, some fragments remain. Protecting those remaining areas would provide important habitat for the species that rely on them.

We do not document extensive changes in oak woodlands in the hills, but data are suggestive of potential longer term trends that could threaten these habitats in the future. As is common throughout the state, these woodlands may not be regenerating and the stand age structure may not be supportive of a sustaining population. GLO data could be used to compare stand structure to contemporary field measurements to help develop target age class structure as a management goal.

Substantial changes have, however, taken place at the scale of individual sites. We identified a number of areas of historical clearing that could be considered for restoration, with potential significant benefits to the local ecosystem (fig. 6.37, 6.38). Using the tools generated here, finer scale assessments of particular sites of interest can identify opportunities for restoring chaparral, savanna, and woodland.

Figure 6.37. Buckeye capsules. Buckeye nuts from *Aesculus californica* in preparation for planting. (Photo by Abigail Fateman, CCC)

Figure 6.38. Buckeye restoration. Volunteers with Save Mount Diablo planting buckeyes and acorns in Irish Canyon. At top, a young buckeye sapling. (Photos by Abigail Fateman, CCC)

Next Steps

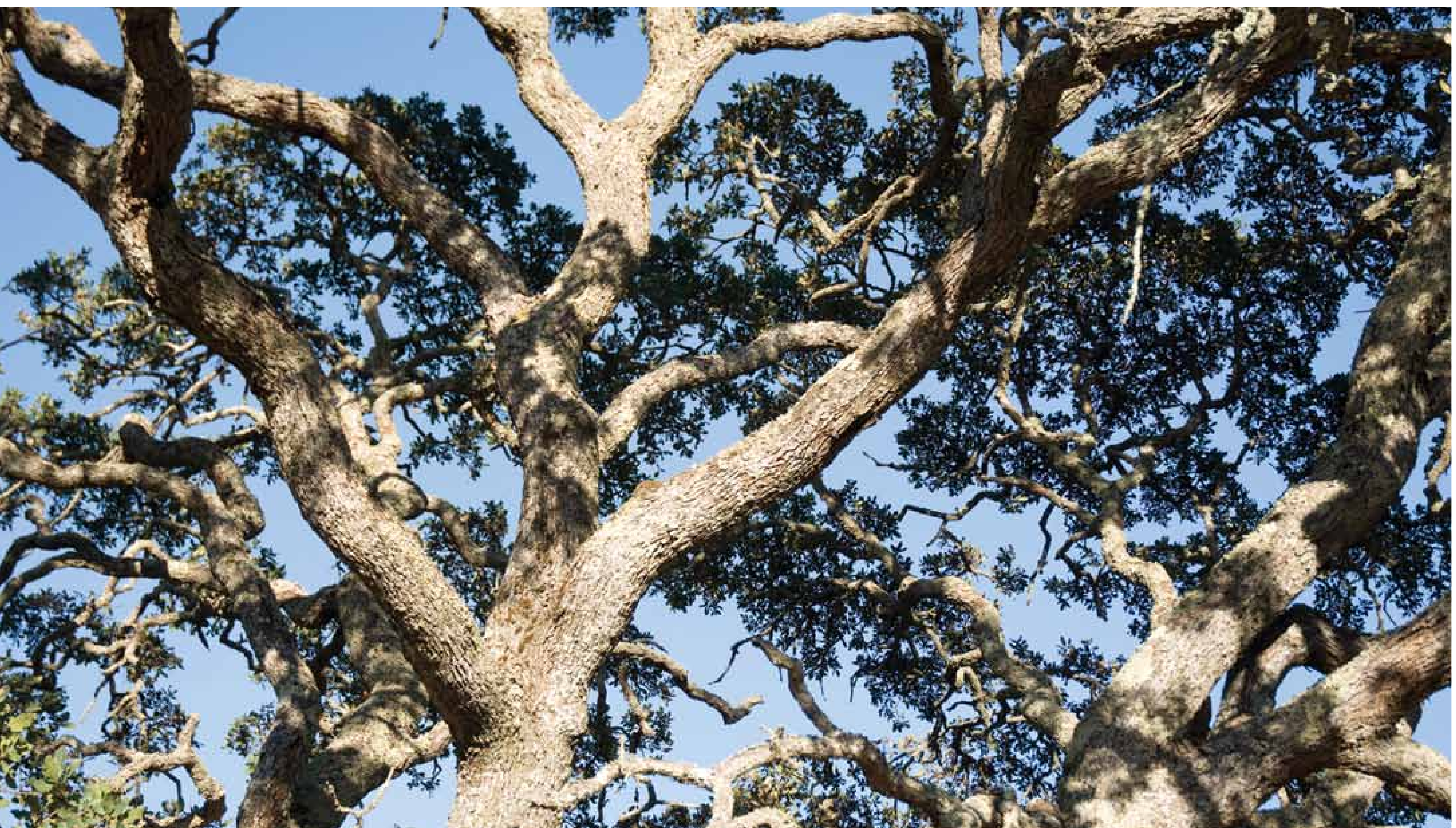
While our analysis did not demonstrate dramatic overall changes in dryland cover in upper elevation regions, smaller scale shifts within subregions and/or topographic settings (e.g., south-facing slopes, foothills) seem evident. Further exploration of vegetation density shifts should be performed in areas of particular concern. Imaging processing software such as ERDAS, Inc. provides sophisticated techniques for detecting such changes between sets of imagery. However, techniques used for processing recent satellite imagery may be limited by the resolution and detail in the 1930s black and white photography. However, methods do exist for using such early imagery and several published studies have used image processing to classify vegetation and detect long-term vegetation change (Carmel and Kadmon 1998, Byrd 2009). Such methods should be adopted if a further investigation of specific areas of change or hypothesis testing is desired.

This mapping effort offers a starting point from which to develop more detailed analyses, like those mentioned above, but we would also suggest that more detailed land use history, particularly for specific parcels or areas of conservation interest, will be important when considering specific restoration targets.

Given uncertainties associated with age class structure and stand density, field measurements should be undertaken to better understand the current age structure (fig. 6.39). It would be valuable to understand whether the areas where tree canopy sizes appeared to increase between 1939 and 2005 represent aging stands. Were a cohort of trees identified (that is, many trees of primarily the same age), it may suggest significant future changes as these trees are lost due to mortality, particularly if recruitment remains low. In addition, such data on contemporary size class distributions could then be compared to the tree sizes from the late 1800s General Land Office survey dataset.

Further research should assess and compare current conditions with these historical datasets to increase our understanding of changes and the potential implications for oak woodland and savanna viability in the face of future fire regime changes and water availability, climate change, and other anthropogenic modifications. Improving our understanding of potential distribution based on relating historical habitat patterns to various factors of change may help us identify and prioritize restoration opportunities in the context of likely future changes.

Figure 6.39. Contemporary dryland habitats Top: View of Mount Diablo from Irish Canyon, scrubby patches of dark green in the foreground are poison oak patches. Bottom: Remnants of historical habitats large and small: (left) A giant spreading oak and (right) a patch of sandy soils. (Left photo by Scott Hein, www.heinphoto.com; Right photos by Abigail Fateman, CCC)



Dryland Habitats

SUMMARY OF FINDINGS

1. **Lowland vegetation was dominated by grassland, but also contained some significant, largely forgotten habitats,** including a 2,800 acre dune scrub patch at Oakley, a large swath of oak savanna east of Brentwood, and an oak savanna in a small alluvial valley near present-day Marsh Creek Reservoir.

2. **Point of Timber was a regionally recognized stand of large valley oaks north of Byron.** These trees were the first large oaks visible when traveling from the south, and extended north and east to the tidal marsh. The low density oak savanna extended west towards Brentwood and north to Oakley.

3. **The Oakley "chamisal," a large patch of interior dune scrub, was an unusual and defining feature of ECCC.** The scrub formed an impenetrable stand and was an important local landmark. Today, remnants at the Antioch Dunes and in the vicinity of Oakley continue to support live oaks, silver bush lupine, and silvery legless lizard, as well as a host of specialized Antioch Dune species.

4. **Scattered oaks were found in the lowlands, stretching from Antioch to Point of Timber.** Live oaks dominated the northern sandy soils, while valley oaks were found in the eastern alluvial soils.

5. **Historically the uplands formed a patchwork of chaparral, woodland, grassland, and savanna,** in patterns similar to those present today. Overall, we mapped 96,976 acres of grassland (58,840 acres in HCP), 17,067 acres of savanna (5,894 acres in HCP), 25,290 acres of woodland (25,198 acres in HCP), 3,310 acres of chaparral (3,016 in HCP), and 8,503 acres of interior dune habitat.

6. **The greatest losses in woodland, savanna, and grassland habitat have occurred in the plains region,** as a result of urban development and agriculture.

7. **Modification of upland vegetation has occurred at the local scale.** At the parcel-level, localized changes were apparent, but did not appear to translate to regional patterns of change in habitat type, at least over the last 80 years.

8. **In the uplands, some evidence was found for changes in stand density within particular habitat types.** Growth of individual trees may result in increases in density. In other cases, particularly in the foothills, individual tree losses are detectable, resulting in a decrease of density. Such losses may be due to mortality and a lack of regeneration as opposed to cutting.

9. **Our mapping shows some pronounced areas of local change** due to cutting in the foothill and montane regions. The areas of greatest woodland loss since the 1930s occurred in the upper Marsh Creek watershed.

10. **Significant habitat type boundary changes due to fire regime change, grazing, or invasive species are not clearly evident in our mapping.** These processes appear, at least in some cases, to have resulted in density changes rather than a shift of vegetation type.

MANAGEMENT IMPLICATIONS AND NEXT STEPS

1. **This mapping effort is a starting point** to develop questions and further research and analysis for future localized or topical projects (i.e., detailed land use and fire history, remote sensing techniques to classify vegetation and detect change). Local-scale restoration projects could benefit from more detailed historical analysis and on-the-ground assessments of individual parcels building on these datasets.

2. **Further research on parcel-scale land use trajectories could help extend the 1930s upland mapping further back in time.** For example, information on burning and clearing practices and property ownership in the historical period would clarify interpretations of 1930s vegetation patterns. This information could also help land managers understand why tree and chaparral density have increased in some areas and decreased in others.

3. **Future research to determine the age structure of woodlands and savannas,** such as ground truthing and tree coring, could help decipher mid-1800s conditions and lend insight into stand density shifts. For example, studies of some blue oak woodlands in California suggest that single age cohorts can dominate the area, which would affect assumptions about mid-1800s conditions. This research should also consider potential future threats as a result of climate change.

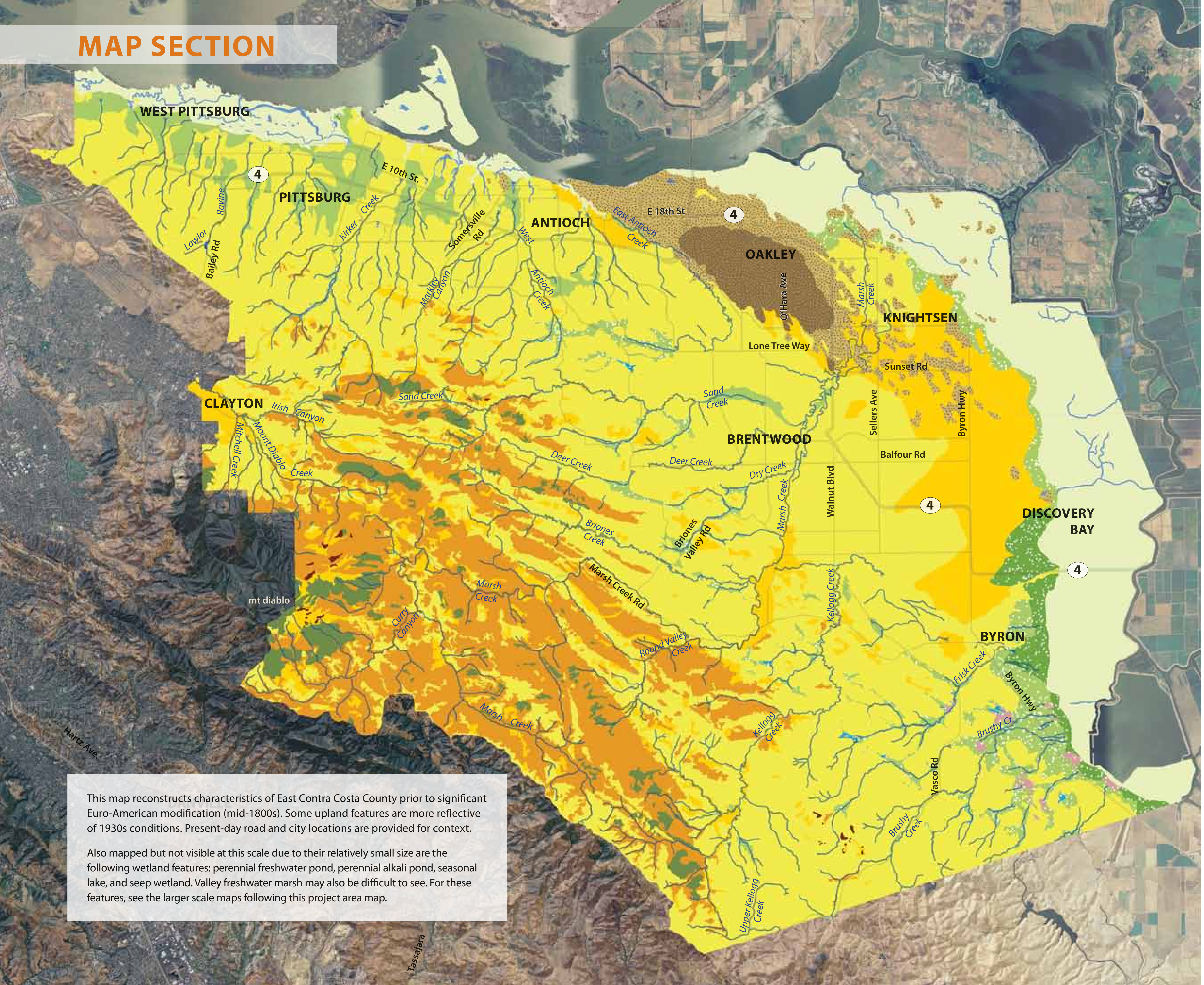
4. **Patches of interior dune scrub still exist and still support native flora and fauna,** including the distinctive silver bush lupines and live oaks. The potential significance of these areas should be considered in coordination with willing land owners.

5. **Planting blue oaks, particularly within foothill savannas and small alluvial valleys,** may help address the noted loss of individual trees and the overall decline in California blue oak woodlands and savannas.

6. **Some lowland areas provide potential for oak reintroduction.** Scattered oaks could be reintroduced to urban and some agricultural areas and grasslands providing some of the ecological functions of the former habitats. Even low density oaks can provide important habitat for birds and other wildlife.

Figure 6.40. Dryland habitats of ECCC. (Photo by Scott Hein, www.heinphoto.com)

MAP SECTION



HISTORICAL LAND COVER, MID-1800s

- Tidal Marsh, Pond, Slough
- Valley Freshwater Marsh
- Wet Meadow
- Alkali Meadow
- Alkali Sink Scrub
- Alkali Flat
- Alkali Marsh
- Woodland
- Oak Savanna
- Chaparral
- Grassland
- Interior Dune Scrub
- Interior Dune (veg. undefined)
- Rock Outcrops
- Stream
- Distributary

USDA 2005, courtesy of NAIP

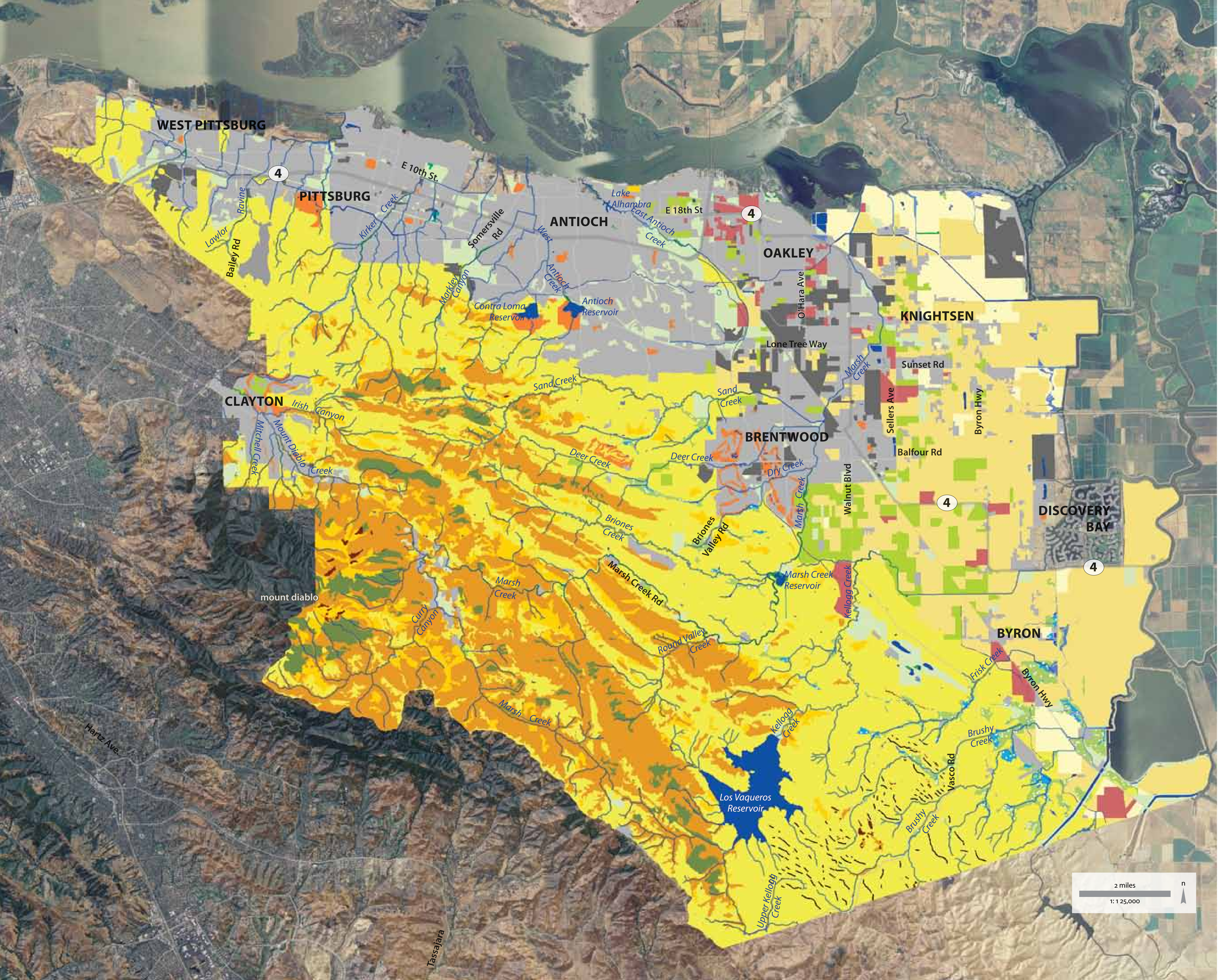
2 miles

1:1 25,000

n

This map reconstructs characteristics of East Contra Costa County prior to significant Euro-American modification (mid-1800s). Some upland features are more reflective of 1930s conditions. Present-day road and city locations are provided for context.

Also mapped but not visible at this scale due to their relatively small size are the following wetland features: perennial freshwater pond, perennial alkali pond, seasonal lake, and seep wetland. Valley freshwater marsh may also be difficult to see. For these features, see the larger scale maps following this project area map.



CONTEMPORARY LAND COVER (HCP/NCCP Jones & Stokes 2006)

- Slough, Channel
- Aquatic, Aqueduct, Pond
- Wetland
- Seasonal Wetland

- Alkali Grassland
- Alkali Wetland

- Woodland
- Oak Savanna
- Chaparral
- Grassland
- Ruderal
- Riparian

- Rock Outcrops

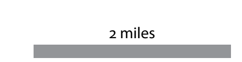
- Pasture
- Cropland
- Orchard
- Vineyard

- Urban/Future Urban
- Non-native Woodland
- Turf
- Wind Turbines
- Landfill

- Stream

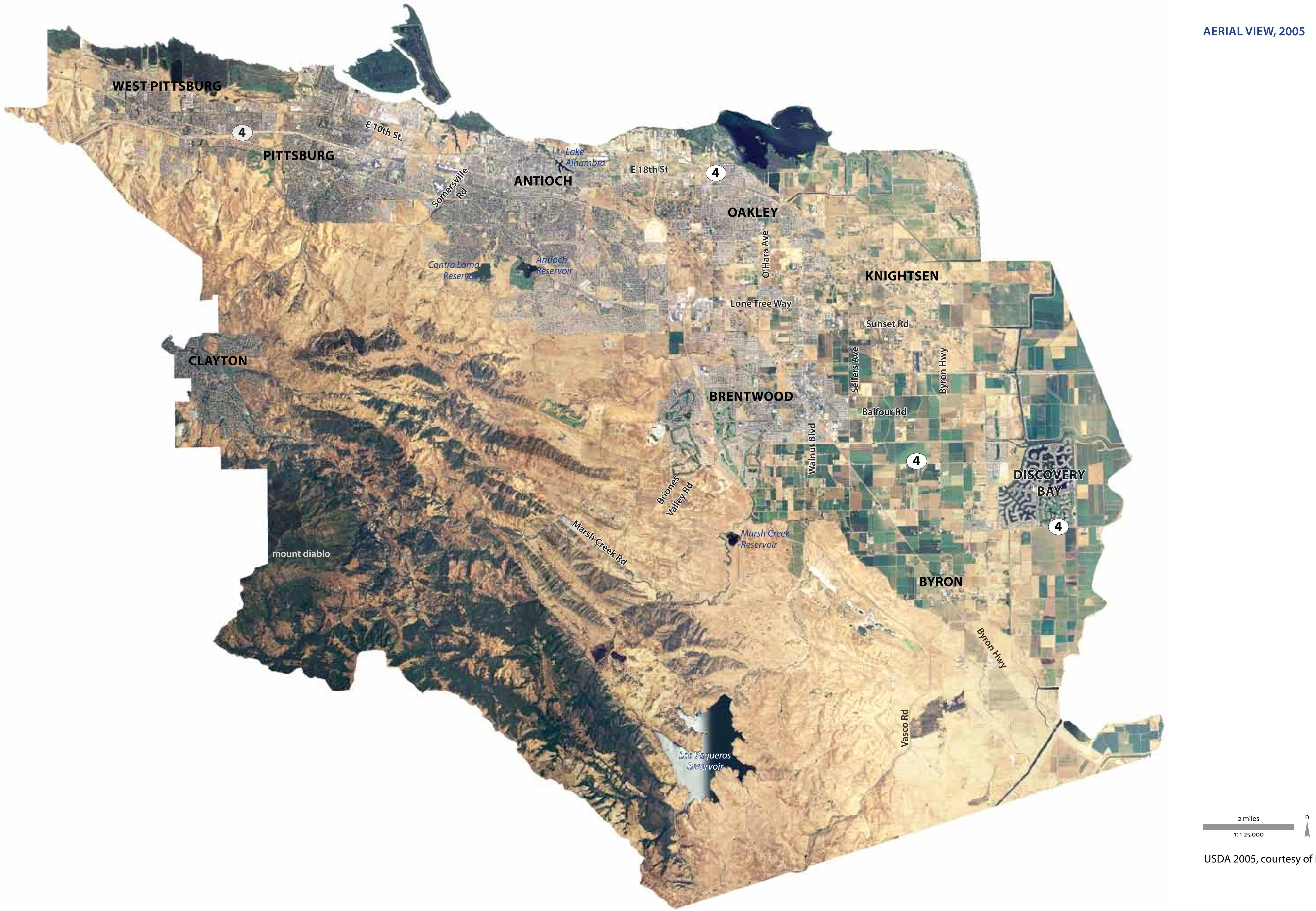
USDA 2005, courtesy of NAIP

AERIAL VIEW, 1939



USDA 1939, courtesy CCC and Earth Sciences & Map Library, UC Berkeley

AERIAL VIEW, 2005



USDA 2005, courtesy of NAIP

HISTORICAL LAND COVER, MID-1800s
Northwestern section of study area

- Tidal Marsh, Pond, Slough

- Valley Freshwater Marsh
- Perennial Freshwater Pond
- Seasonal Lake/Pond
- Wet Meadow

- Alkali Meadow
- Alkali Flat
- Alkali Marsh

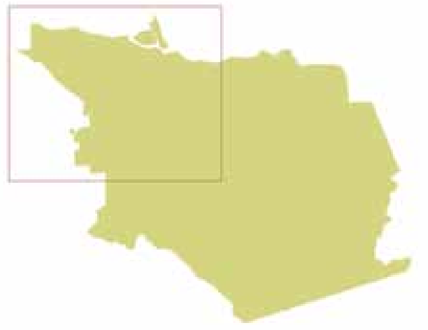
- Woodland
- Oak Savanna
- Chaparral
- Grassland
- Interior Dune (veg. undefined)

- Rock Outcrops

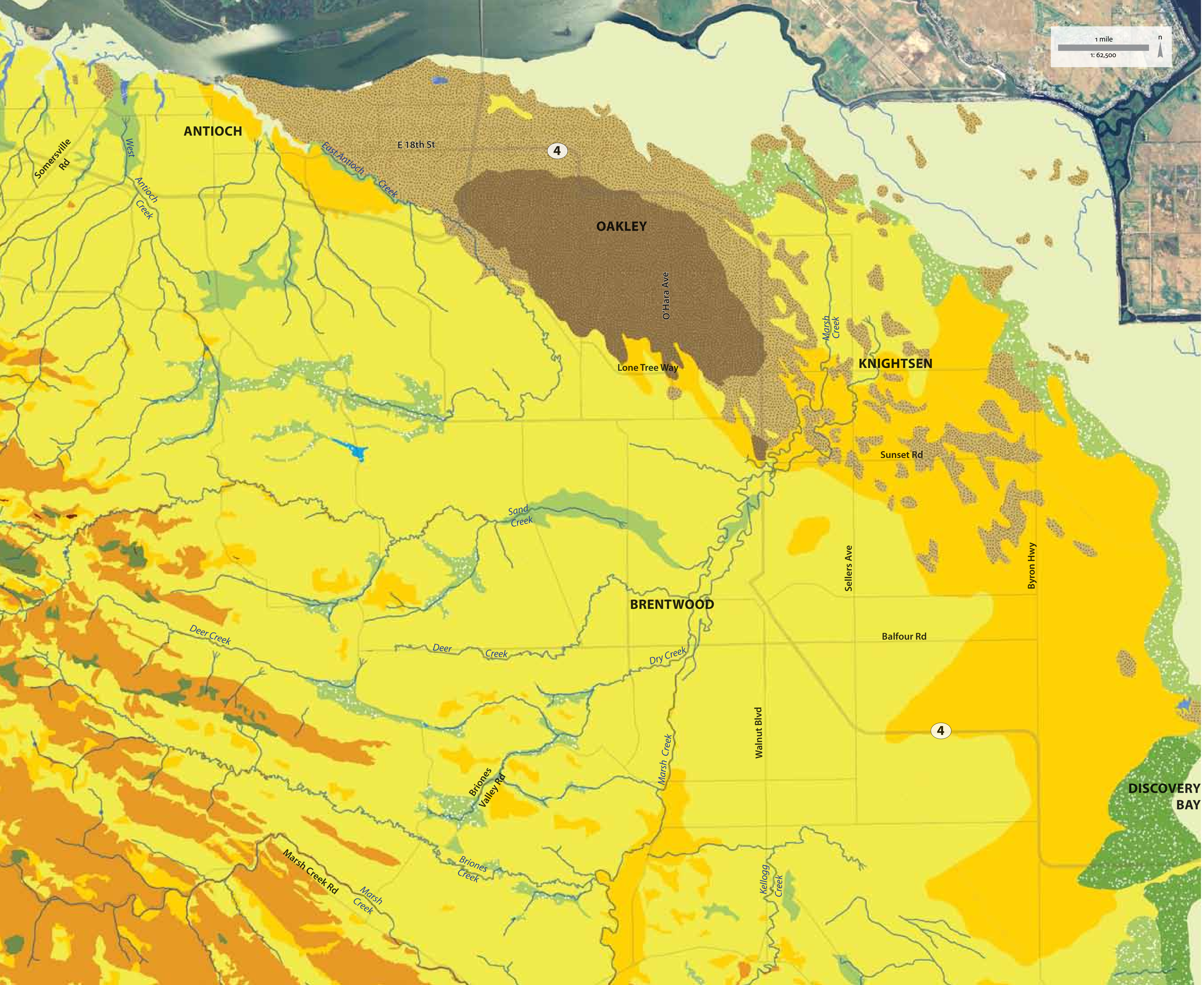
- Stream
- Distributary
- Spring

USDA 2005, courtesy of NAIP

AERIAL VIEW, 2005
Northwestern section of study area
with contemporary drainage network



USDA 2005, courtesy of NAIP



HISTORICAL LAND COVER, MID-1800s
Northeastern section of study area

Tidal Marsh, Pond, Slough

Valley Freshwater Marsh
Seasonal Lake/Pond
Wet Meadow

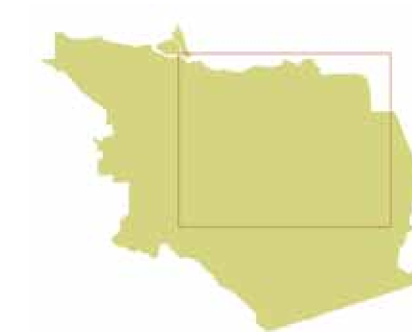
Alkali Meadow
Alkali Sink Scrub
Alkali Flat
Alkali Marsh

Woodland
Oak Savanna
Chaparral
Grassland
Interior Dune Scrub
Interior Dune (veg. undefined)

Rock Outcrops

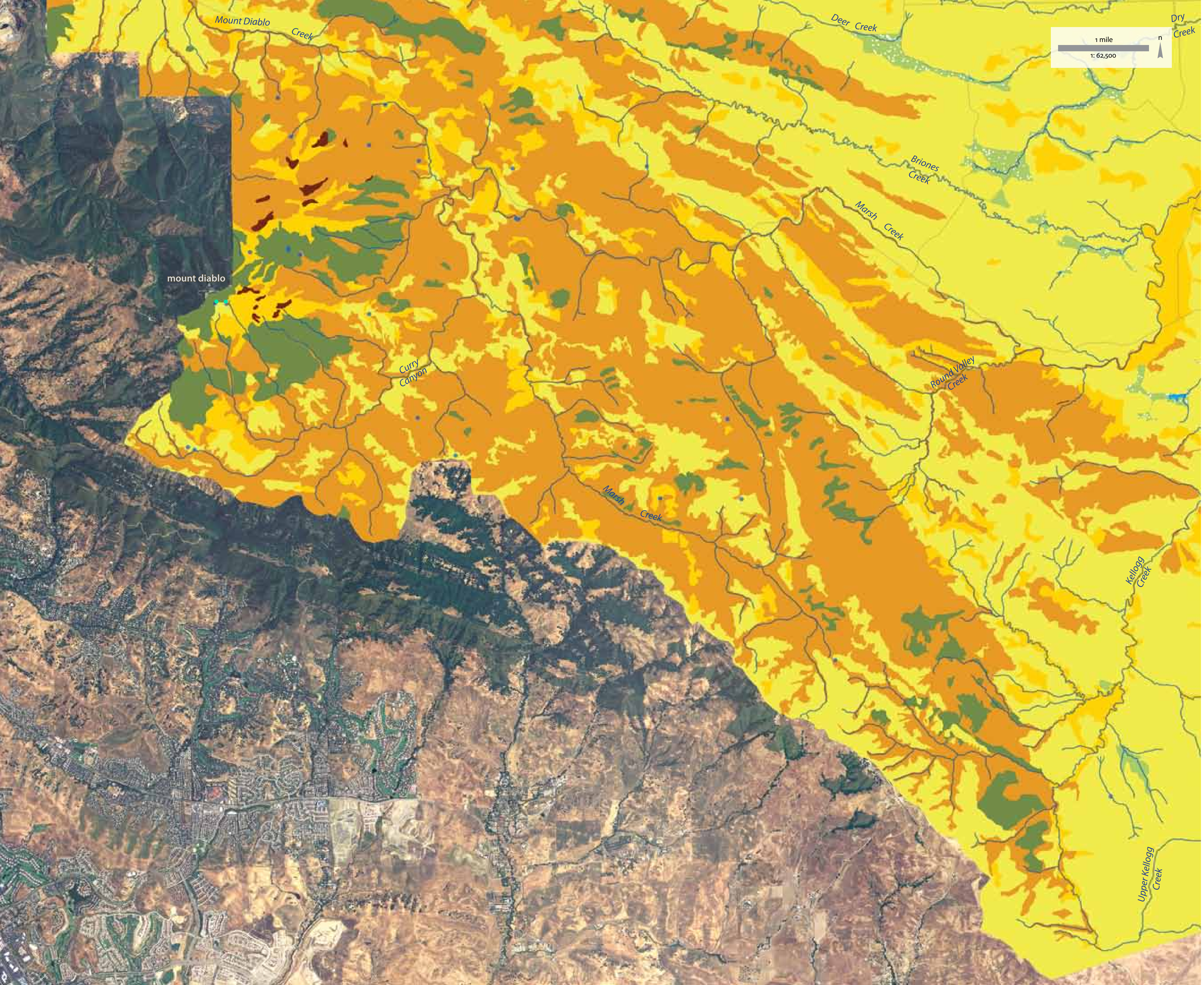
Stream
Distributary
Spring

USDA 2005, courtesy of NAIP



AERIAL VIEW, 2005
Northeastern section of study area
with contemporary drainage network

USDA 2005, courtesy of NAIP



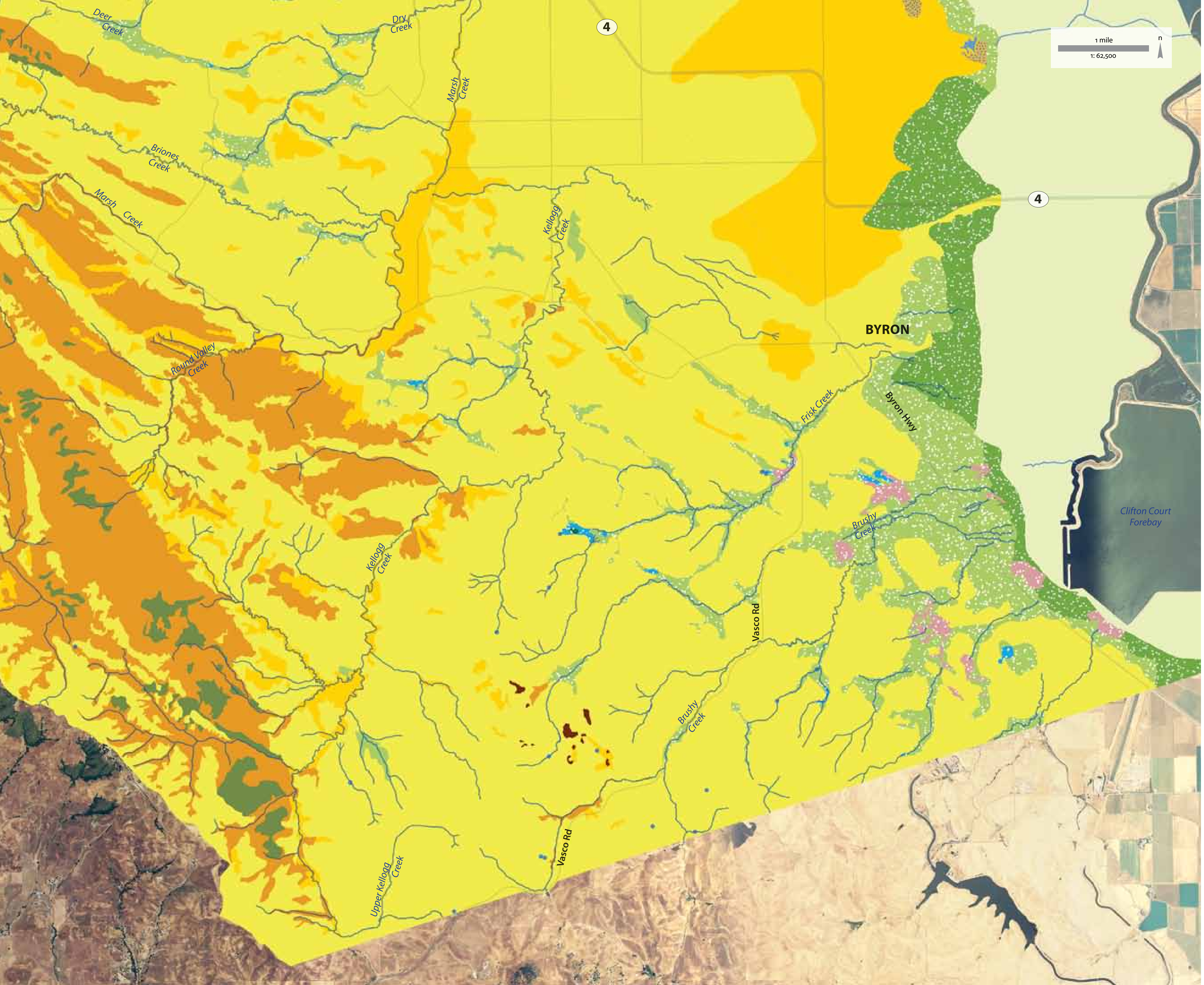
HISTORICAL LAND COVER, MID-1800s
Southwestern section of study area

- Seasonal Lake/Pond
- Seep Wetland
- Wet Meadow
- Alkali Meadow
- Alkali Marsh
- Woodland
- Oak Savanna
- Chaparral
- Grassland
- Rock Outcrops
- Stream
- Distributary
- Spring

USDA 2005, courtesy of NAIP

AERIAL VIEW, 2005
Southwestern section of study area
with contemporary drainage network

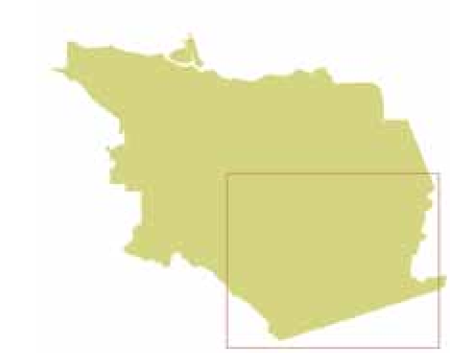
USDA 2005, courtesy of NAIP

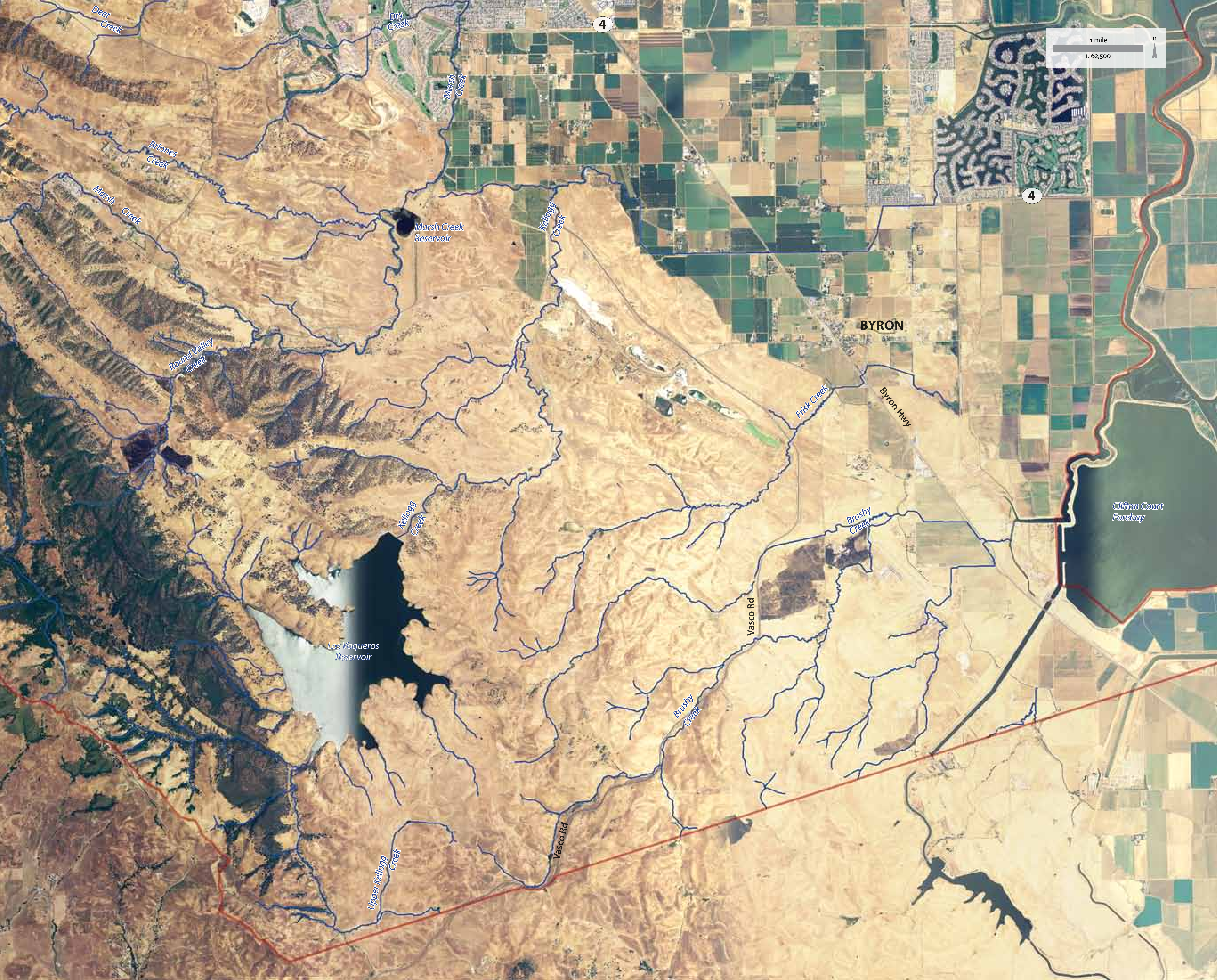


HISTORICAL LAND COVER, MID-1800s
Southeastern section of study area

- Tidal Marsh, Pond, Slough
- Valley Freshwater Marsh
- Perennial Freshwater Pond
- Wet Meadow
- Alkali Meadow
- Alkali Sink Scrub
- Alkali Flat
- Alkali Marsh
- Perennial Alkali Pond
- Woodland
- Oak Savanna
- Chaparral
- Grassland
- Interior Dune (veg. undefined)
- Rock Outcrops
- Stream
- Distributary
- Spring

USDA 2005, courtesy of NAIP





AERIAL VIEW, 2005
Southeastern section of study area
with contemporary drainage network

USDA 2005, courtesy of NAIP

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APPENDIX: DETAILED METHODS

WETLAND CHAPTER

Mapping Tidal Marsh

We used a combination of 19th and 20th century data sources to reconstruct the location of historical tidal marsh. In particular, we focused on determining the location of the tidal marsh-upland boundary. Defining the historical extent of tidal marsh in East Contra Costa County is somewhat more complicated than in other parts of the San Francisco Bay. The 1850s-era U.S. Coast Survey (USCS) Topographic-sheets (T-sheets), which provide a highly accurate and detailed (1:10,000 scale) delineation between tidal marsh and solid land for most of the Bay margin (Grossinger et al. 2005), do not exist for most of East Contra Costa County. The northern shoreline bordering Suisun Bay was not mapped by the Coast Survey until 1866, and then only at a relatively coarse, low resolution (1:20,000). Along the Delta margins, the Coast Survey produced no detailed maps before extensive levees were built. Data were available to define most portions of the shoreline, but alternative, often more recent, sources were used.

The northern shoreline, between Port Chicago and Antioch, was mapped at 1:10,000 scale in the 1880s as part of the resurvey of the San Francisco Bay shoreline by the U.S. Coast and Geodetic Survey (as the agency was referred to at that time). Three T-sheets (1803 (Davidson 1886a), 1830 (Davidson 1887), and 1793 (Davidson 1886b)) provide detailed pictures of the shoreline at that time. The bayward marsh margins as represented in 1866 and 1886 mapping correspond closely, suggesting a stable shoreline during this time and accurate mapping. We digitized boundaries from the later maps because of their greater scale and spatial accuracy for both the bayward and landward margins. In a few places, the landward margin showed evidence of modification (e.g., straight boundaries following the railroad, early factory sites), or features shown in 1886 were not present on the earlier map. In these cases, we supplemented the boundary shown by the 1880s T-sheets with additional data, including the 1866 USCS map (Rodgers and Chase 1866); an early property survey (Robinson 1880); the zero and five foot contours from the Collinsville and Honker Bay USGS quadrangles (1918); and the early soil survey (Carpenter and Cosby 1933). We also compared this reconstructed shoreline to the previous estimate by Atwater (1982) based on the 1918 USGS Collinsville map (the westernmost extent of Atwater's mapping).

Tidal marsh sloughs shown by Rodgers and Chase (1866) and Davidson (1886) were integrated to maximize accuracy and detail. Where features were shown similarly by both maps, we used the later map because of its greater spatial accuracy. A number of smaller sloughs were added based on their presence on the earlier map. The 1866 T-sheet also showed a number of substantial marsh pannes not shown by other sources.

East of Antioch, later T-sheets were not available. Atwater (1982) delineated this margin as part of a geologic study of Delta soils; his hardcopy maps were later digitized and georeferenced by The Bay Institute (1998).

In the absence of T-sheets, Atwater used remnant marshes indicated by historical USGS quadrangles and topographic contours from the same maps to extrapolate in areas where marshes had already been reclaimed (which was most of the area). Since most extant tidal marsh circa 1982 was found at 2.5-3.5 foot elevation, Atwater defined a probable boundary midway between the zero and five foot contours (Atwater 1982). Nineteenth-century GLO data do, in fact, consistently place the marsh margin between the zero and five foot contour, confirming Atwater's interpretation. (See additional discussion of this source in Drylands Chapter 6.)

Because contemporary wetland and sea level rise planning require an understanding of the Delta margin, we revisited the boundary based on an array of local sources, including the GLO data, the early soils survey, early aerial photography, and historical and modern topographic maps. This new boundary is generally consistent with Atwater's 1982 estimate, but does differ in places (generally by less than 250 feet but up to as much as 1,000 feet in a few places).

GLO surveys indicated the transition to tidal wetlands with phrases such as "enter tule," "enter swamp and overflowed lands," and "to overflowed lands." We included areas described by Carpenter and Cosby's 1939 soil survey report as "subject to inundation at high tide by brackish tidal water" (Carpenter and Cosby 1939:60). Historical topography (USGS 1910 (Jersey), 1912 (Bethany), 1913 (Woodward Island)) provided a detailed depiction of the 5 foot contour line, indicating low areas subject to inundation by the tides. In many areas, prominently dark regions in the early aerial imagery also showed former tidal extent. We integrated these sources to make a best estimate of the tidal marsh boundary on the east side. This is generally a conservative estimate; in places, some sources suggest that tidal marsh could have extended 500 to 1,000 feet further inland. The boundary should be considered a transitional zone, particularly where there is a low topographic gradient to adjacent salt-affected alkali meadows.

Mapping Alkali Extent

To map alkali extent, we used a minimum mapping unit of five acres, although individual polygons may be divided into smaller areas due to different source combinations or due to a change in type (alkali meadow v. alkali marsh). We used four primary mapping sources: the 1933 soil survey map showing alkali-influenced soils and the accompanying report (Carpenter and Cosby 1939), the 1977 soil survey alkali soil types (Marcuse clay, Pescadero clay loam, Sacramento clay, and Solano loam; USDA 1977), a study and map of alkali vegetation types near Kellogg Creek (Jones & Stokes 1989), and HCP mapping (Jones & Stokes 2006). Secondary (supporting) sources included textual descriptions from the GLO survey, the historical aerial imagery, and the contemporary slope raster derived from LIDAR data. Since we found no maps of alkali extent produced prior to USDA soil surveys (locally circa 1930), our estimation of historical alkali extent is based on this source. However, it is supported by additional 19th century textual data.

We used the contemporary HCP mapping of alkali areas as the base layer and used our additional sources to modify boundaries and add additional areas. We did not modify boundaries unless earlier sources showed substantial (> 150 ft) deviation from the contemporary extent. Polygons were split such that each polygon reflects the unique combination of sources that support it. Polygons were then trimmed to fall within a slope of six degrees (10.5%). This slope cutoff is based on observations and general understanding that alkali habitats tend to occur on relatively flat terrain (Howard pers. comm.). The slope cutoff allowed us to use the detail provided by the LIDAR dataset, which was unavailable to the previous mapping efforts from which our original polygons were based.

We attributed polygons based on their primary (digitizing) and secondary (supporting) sources. We assigned certainty levels to each of these sources (table A.1), and applied these to individual polygons. We assigned a high certainty level to "alkali affected" soil types from the 1933 Carpenter and Cosby soil survey as well as to USDA 1977 "strongly alkali" soil types. The Carpenter and Cosby 1933 soil survey had two other means to indicate possible alkali areas: areas defined as "spotted alkali" and areas with descriptions of alkali-influenced vegetation and soils in the accompanying soil survey report. These were assigned medium and low certainty levels, respectively. Other modern sources (Jones & Stokes 1989, contemporary HCP mapping) were assigned a medium certainty level, reflecting the presumption of historical presence. Soil types from the USDA 1977 soil survey that were associated with alkali, but were not specifically assigned as an "alkali" subseries were attributed with a low certainty level. In the cases where multiple sources contributed to a single polygon, certainty levels were assigned according to the source with highest level associated with a particular polygon. Approximately 10% of our mapped alkali received a low interpretation certainty, while 65% received high certainty.

Our sources occasionally provided conflicting information. In some cases, areas that were explicitly mapped as alkali 'free' by Carpenter and Cosby (1933) fell within an alkali zone from the 1977 soil survey, and so received a classification as low-certainty alkali. (A classification as "free" indicates alkali level of less than 0.2 % in the top six feet of soil (Carpenter and Cosby 1939).) This difference in classification could reflect an error in either soil survey, a change in conditions, or a difference in alkali mapping threshold.

Table A.1. Interpretation certainty levels associated with individual and multiple sources used to map historical alkali grassland and wetland extent. Certainty levels were assigned according to the source with highest level associated with a particular polygon.

Source_1	Interpretation Certainty
Carpenter and Cosby 1933, alkali affected	High
Carpenter and Cosby 1933, spotted alkali	Medium
Carpenter and Cosby 1933, or USDA 1977, soils description includes discussion of salt tolerant plants	Low
Jones & Stokes 1989	Medium
USDA 1977, strongly alkali	High
HCP 2009	Medium

Alkali Classification Crosswalk

The four historical alkali subtypes differ from those developed for the 2006 HCP (Jones & Stokes 2006). For the HCP, alkali habitats were divided into alkali grassland and alkali wetland; alkali wetland included both seasonal and perennial wetlands. Our classification distinguishes seasonal and perennial wetlands, albeit potentially with a more inclusive definition of seasonal wetlands, as our meadow class can include regions that are flooded only temporarily. The differences in approach and source materials prevent a direct correspondence between the subtypes of the two classification systems. In general, areas mapped as alkali grassland by the HCP correspond to historical alkali meadow and alkali sink scrub, while HCP alkali wetland could correspond to any of the four classification subtypes (see table A.2). Total past and present extent can be compared by lumping all alkali-influenced habitats.

Although some studies (including Jones & Stokes 1989, 2006) have distinct alkali meadow and alkali grassland classes, these are often indistinguishable and considered equivalent terms (Jones & Stokes 1989). Our alkali meadow class includes areas of alkali grassland as classified by the HCP (Jones & Stokes 2006). Alkali grassland and meadow are both dominated by herbaceous species, but grasslands have more annual species, while meadows have more perennial species (Jones & Stokes 1989).

Table A.2: Crosswalk between HCP and historical ecology alkali habitat types.

Historical Ecology classification	HCP classification	Seasonality
alkali marsh	alkali wetland	perennial wetland
alkali playa	alkali wetland	seasonal wetland
alkali sink scrub	alkali wetland or grassland	seasonal wetland
alkali meadow	alkali wetland or grassland	seasonal wetland

DRYLAND CHAPTER

Density Estimations

We performed quantitative analysis of the GLO bearing tree dataset by calculating point density estimates. This information was used to estimate average densities for selected populations and to compare across different regions of the study area. Various different methods have been used to estimate density based on GLO bearing tree data (Bouldin 2008). The most commonly used is the point-centered quarter method developed by Cottam and Curtis (1956), who showed empirically that density is equal to the inverse of the square of the mean distance from a point to a tree (Radeloff et al. 1999). However, this method is problematic with a small sample size or when applied to populations with large-scale non-randomness (Bouldin 2008). For this reason, we also used the more robust Morisita (1957) formula:

$$D = \left(\frac{gk-1}{N}\right)\sum_{i}^{N}\frac{k}{\pi\sum_{j=1}^{k} r_{ij}^{2}}$$

where g is the bearing tree distance rank for the quadrant (g=1), k is the number of quadrants with bearing trees, N is the number of survey points, r is the distance from the survey point to a bearing tree, and i and j are the index numbers for the survey points and quadrant numbers. By estimating density at single points prior to aggregating across an area, this method avoids some of the limitations of the point-centered quarter method. For this equation, we must assume that the trees are randomly distributed locally about a single survey point and that the points are well distributed across aggregated areas. Unfortunately, this method requires two or more bearing trees, and thus we used only a subset of the survey points with bearing trees.

Although the possible bias mentioned above could influence the results, the differences across regions reflect actual variability and would allow for comparison to size and population distribution today, if such surveys were carried out.

Density Change Detection Using Raster Analysis

To explore within-habitat class density shifts over the past 70 years and the type of change, we developed a preliminary method of raster image analysis that would, for a given area, show the location as well as trajectory of change between woody vegetation cover (chaparral or trees) and no cover (grassland). A true analysis to test vegetation change hypotheses using remote sensing techniques was outside the scope of the project. Also, the most common remote sensing methods are not options when using historical imagery as it is composed of a single color band, whereas the contemporary color NAIP imagery is composed of three bands: Red, Green, and Blue. In order to use the same methods on both sets of imagery, we averaged the pixel values of the 3-band NAIP imagery to create a single-band contemporary dataset. This resulted in two comparable datasets, each with pixel values ranging from 0 (black) to 255 (white). We used the Spatial Analyst extension of ArcGIS to perform the raster analysis.

We used methods of gray tone density slicing (Mast et al. 1997) with the contemporary and historical imagery to determine areas of tree cover and those without. We determined a range of pixel brightness values that exemplified tree cover and reclassified the raster data into binary images with pixels of cover and no cover. This provided a systematic and efficient way to determine extent of cover and no cover and detect change between the 1939 and 2005 imagery. We did not perform comprehensive analysis, but provide examples of possible approaches and outcomes.

However, this method requires that a single pixel value be chosen for each image that represents the breakpoint between cover and no cover. That is, determining the pixel values that represent cover versus no cover is dependent on visual analysis and the breakpoint will vary from image to image, so no single standard pixel value can be used for both the historical and contemporary imagery. Therefore, it is inevitable that some areas of shadow and darker grass will have lower pixel values than the chosen breakpoint and will be included in the "cover" class, while some light-toned trees with higher pixel values than the chosen breakpoint will be included in the "no cover" class. For each analysis, several breakpoints were chosen to explore the sensitivity of the results to slight changes in the break points. Difficulties also arise when the images were taken at different times of the day, resulting in shadows at different angles and sizes. Corrections for slope, aspect, and solar insolence have been utilized with varying success by other researchers (Teillet et al. 1982, Carmel and Kadmon 1998), but were too extensive to include here. This is of particular concern when evaluating change in factors affected by variables such as slope and aspect. Finally, overall percentage of change is likely overemphasized given slight orthorectification errors (i.e., trees do not necessarily overlap perfectly).