

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 aeriels, 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.

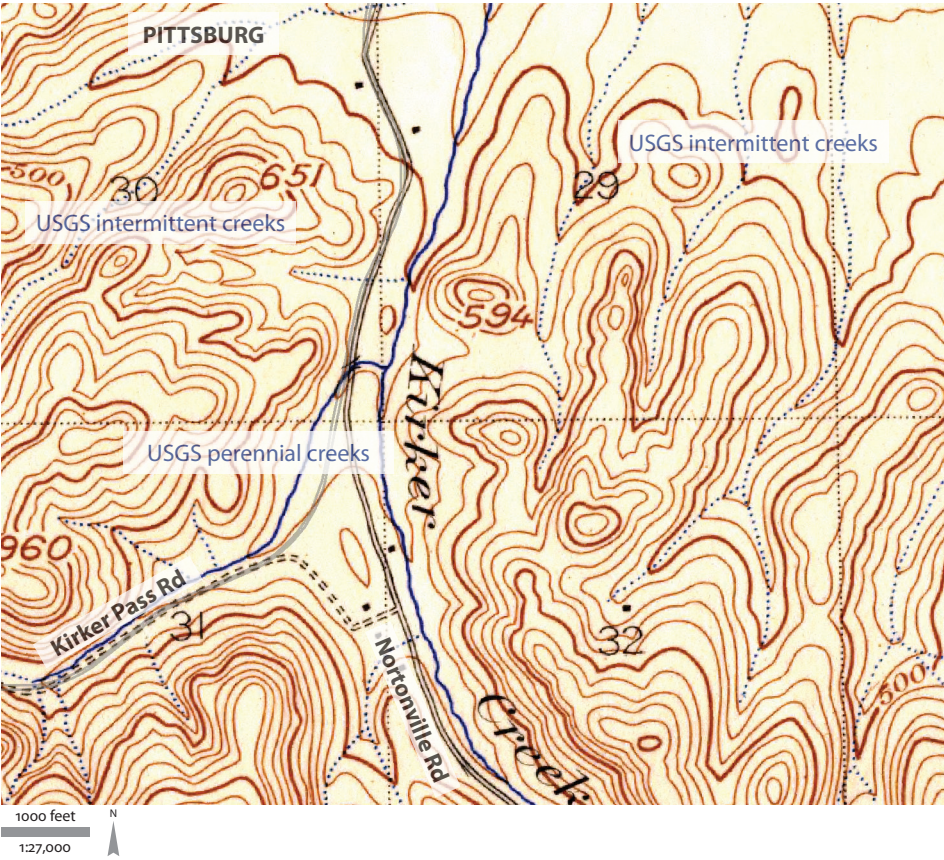


Figure 4.2. Perennial and intermittent stream reaches. Historical USGS quadrangles recorded the seasonality of stream reaches, using a thick “blue line” to indicate a perennial reach and a dashed or dotted line to indicate an intermittent or ephemeral reach. We coded our stream network using this data, 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

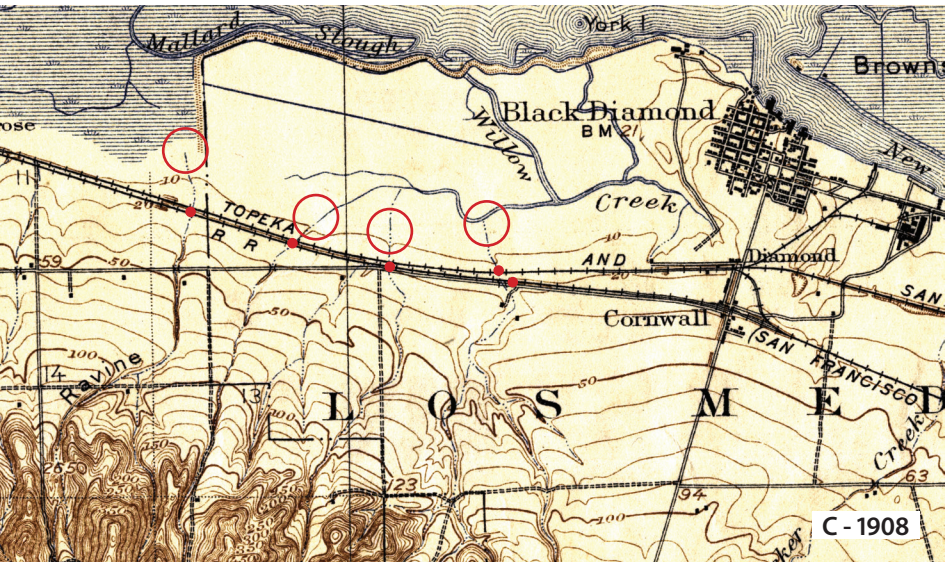
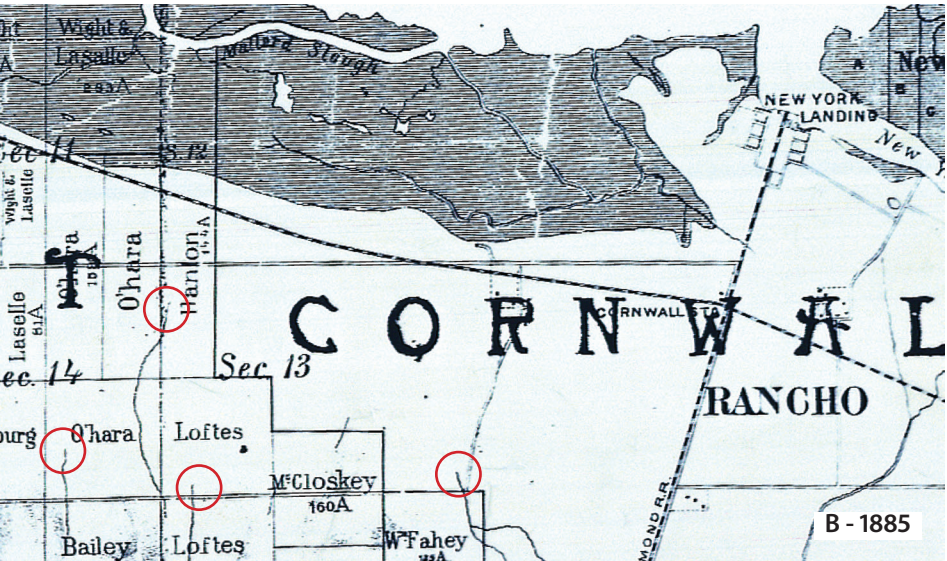
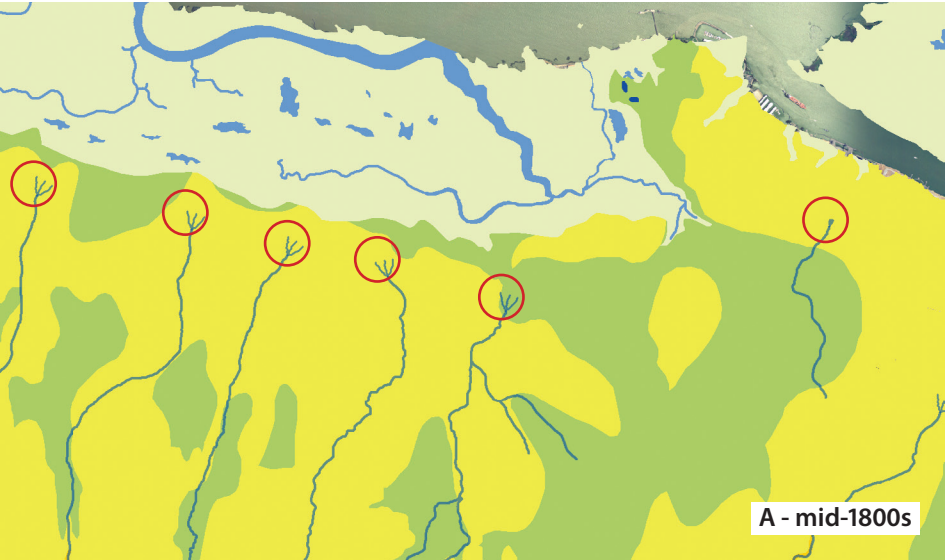


Figure 4.3. Discontinuous northern drainages. A) Most northern drainages did not connect directly to the tidal marsh in the mid-1800s, as shown here in the historical habitat and channel map developed for this project. B) Early maps show the pattern of defined channels extending some distance onto the 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.

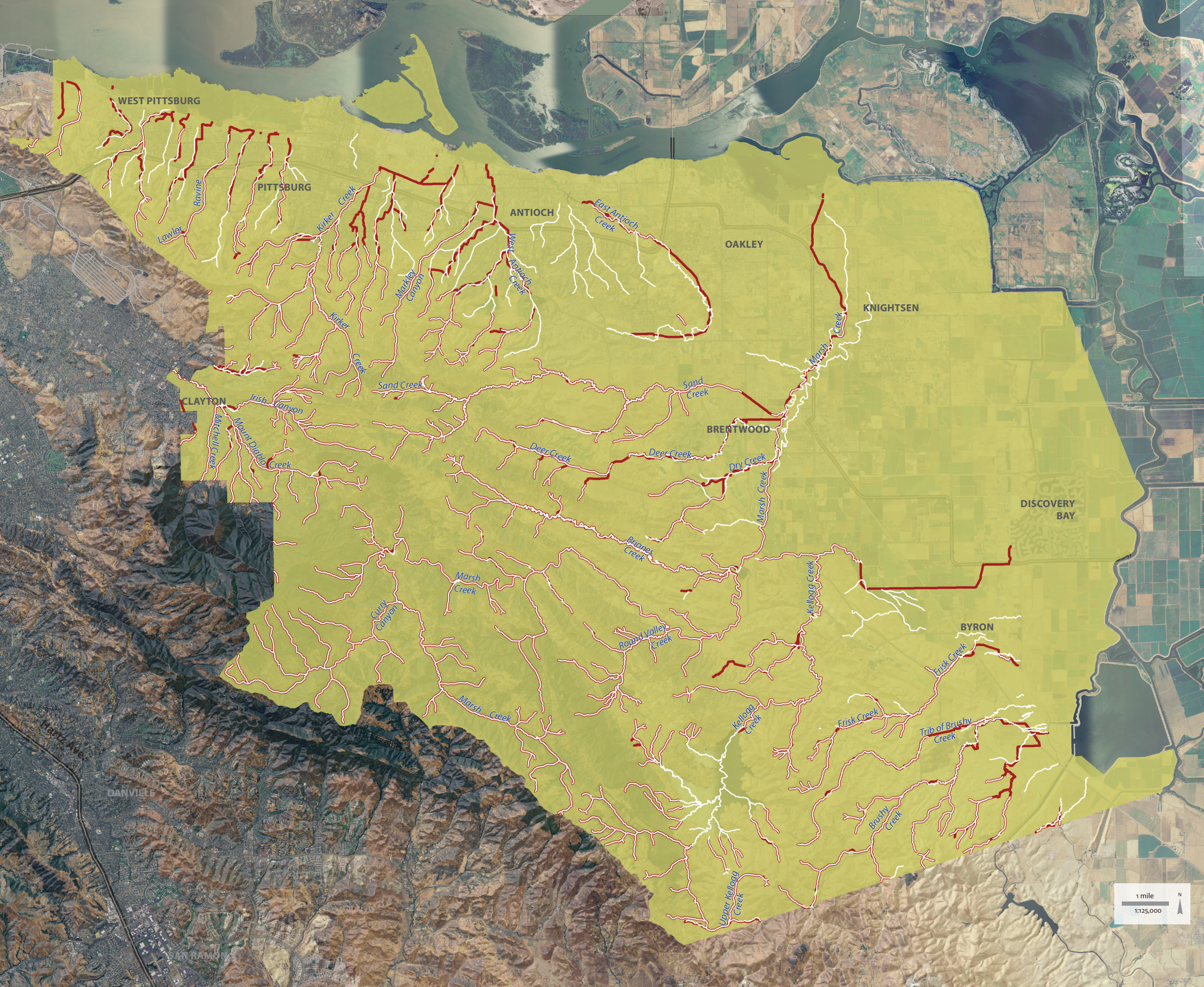
In the foothill region the contemporary network differs from the historical network for 25% of its 230 mile length. Much of this is due to the construction of the Los Vaqueros Reservoir on Kellogg Creek. Excluding Kellogg Creek, only 12% of the contemporary channel length (22 miles) differs from the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



- Historical channel
- Artificial channel
- Historical and present-day alignment

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.

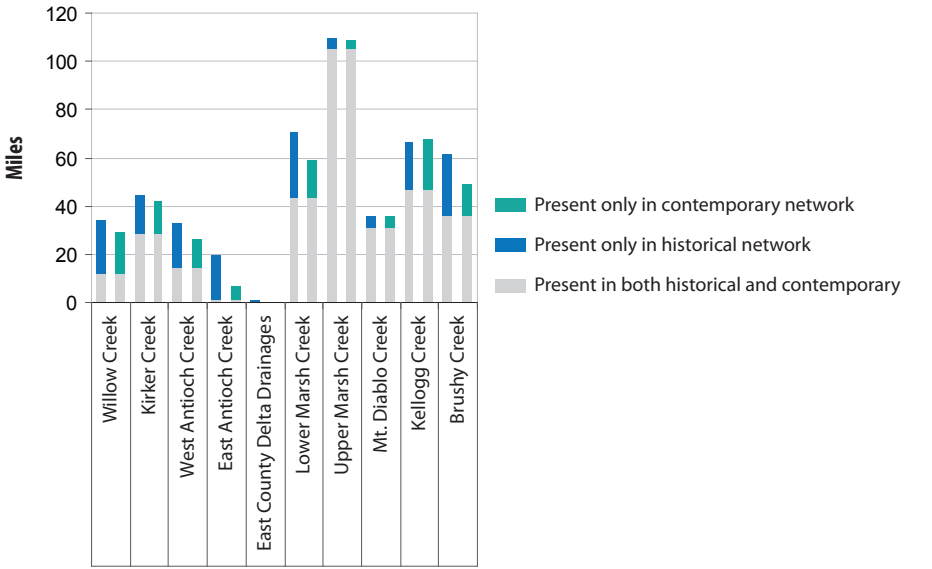


Figure 4.7. Stream modification by watershed. The colored bars represent the miles of each network that differ between historical and present-day periods. Miles of stream present only in the contemporary network are miles that have been added to the contemporary network. Miles of stream present only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

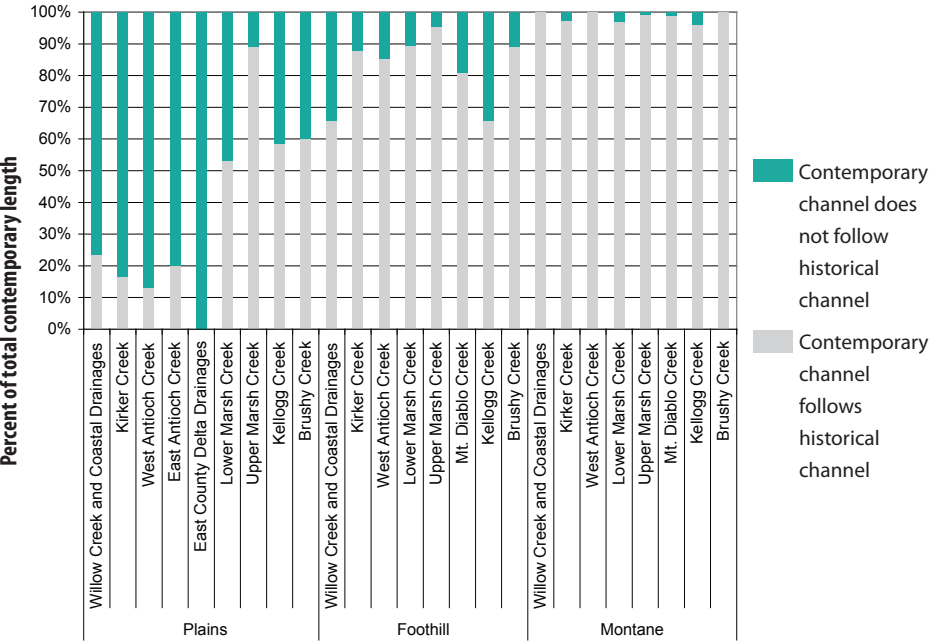


Figure 4.9. Stream modification by watershed and geomorphic unit. In general, stream reaches in the plains geomorphic unit have been heavily modified; foothill and montane units display much less alteration. For more details on the types of altered channels present in ECCC, see the Watershed Atlas (Contra 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 Askeveld; August 28, 2008 by Scott Hein, www.heinphoto.com; March 27, 2011 by Brad Heckman, Save Mount Diablo)

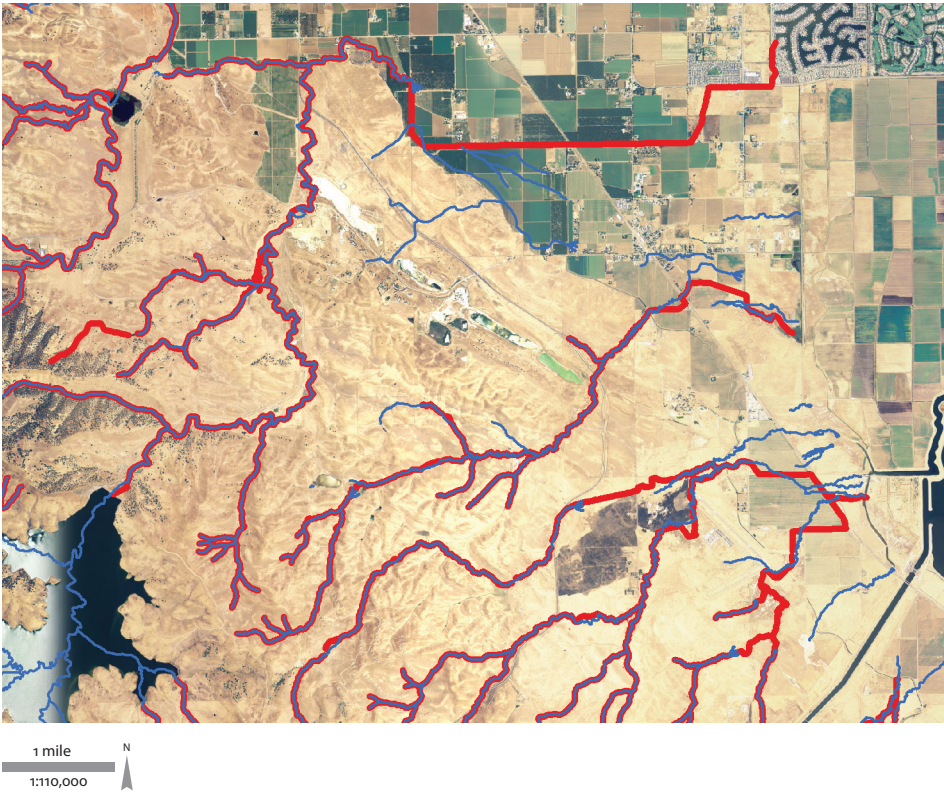
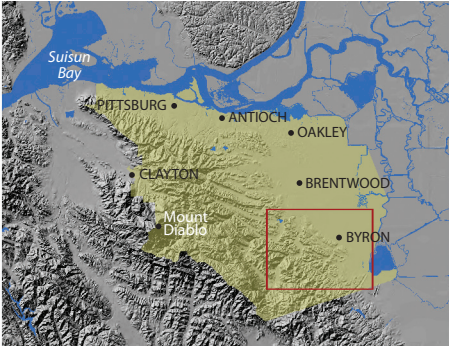


Figure 4.10. Changes in the southeastern drainage network. The contemporary network (shown in red) of Kellogg and Brushy creek watersheds has extended and straightened portions of the historical network (blue) to make it much more continuous. (USDA 1939, courtesy of NAIP)

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 acres 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

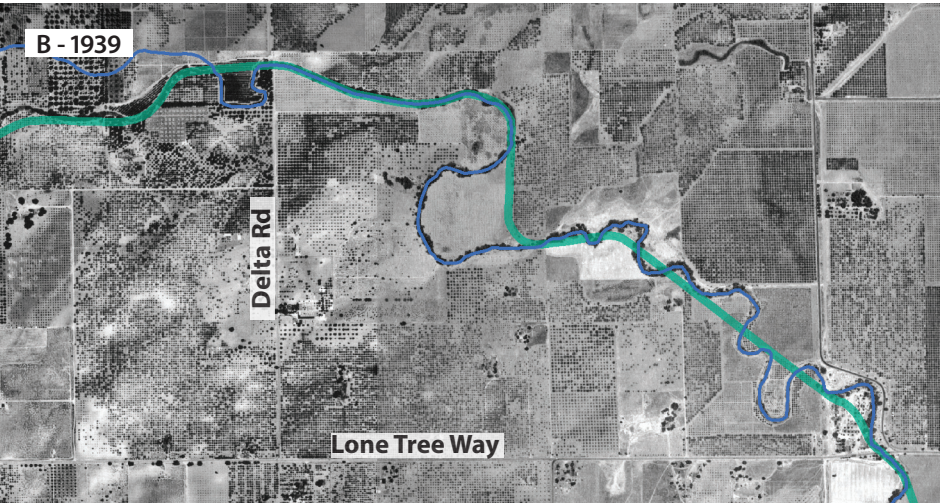
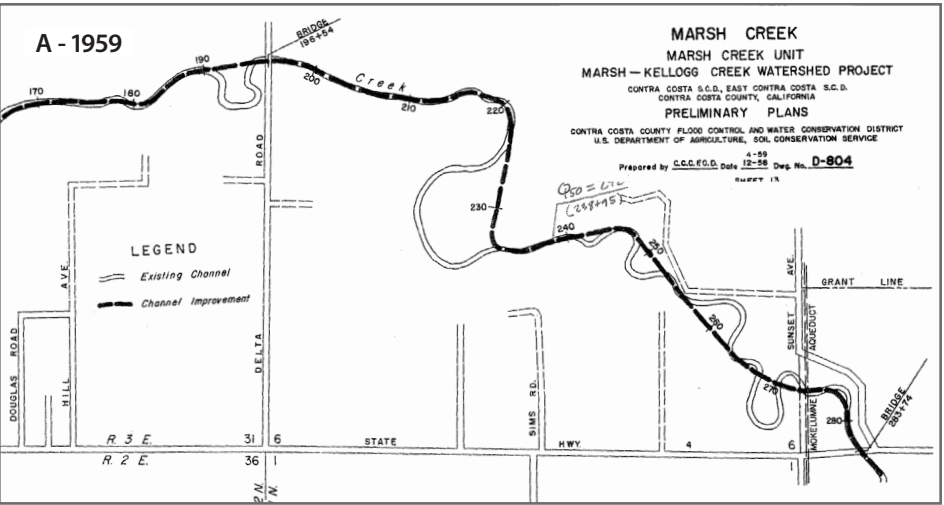


Figure 4.11. Modifications to Marsh Creek. The engineering map (A) shows a 1959 design to remove several meanders from Marsh Creek. These meanders can clearly be seen in the historical aerials (B) and have been removed today (C). In B and C the historical network is shown in blue, overlaid on the present 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)



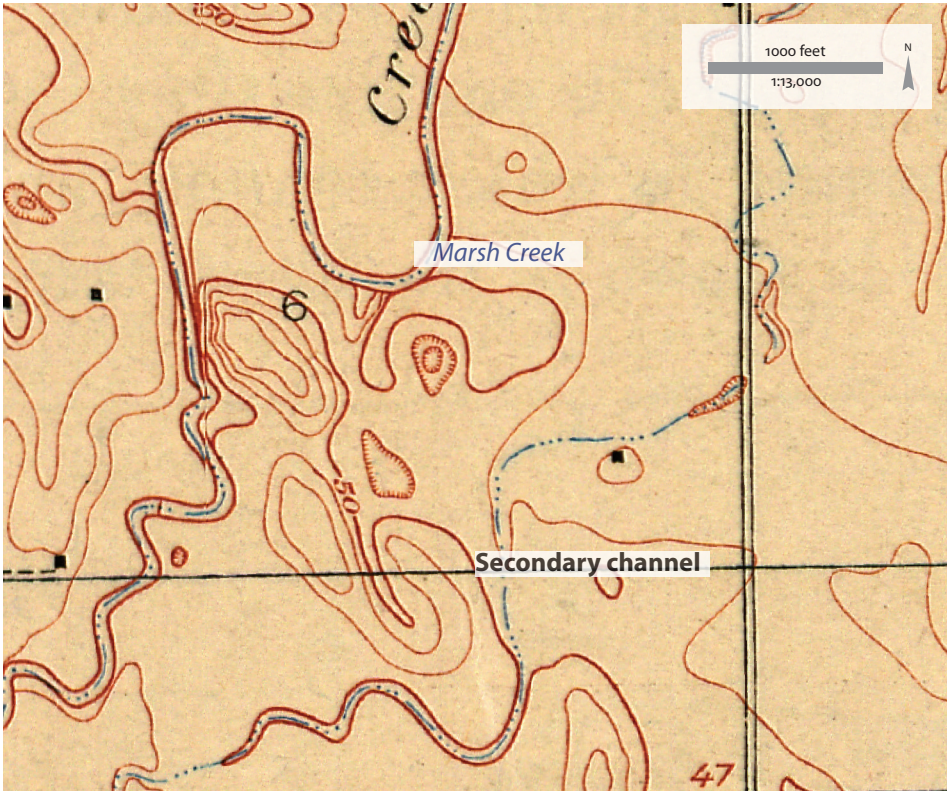


Figure 4.12. Secondary channel of Marsh Creek. (left) Below its confluence with Deer Creek, Marsh Creek historically split into two channels. The eastern channel functioned as an overflow or secondary channel through the historical period, but in prehistoric times may have served as the primary channel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

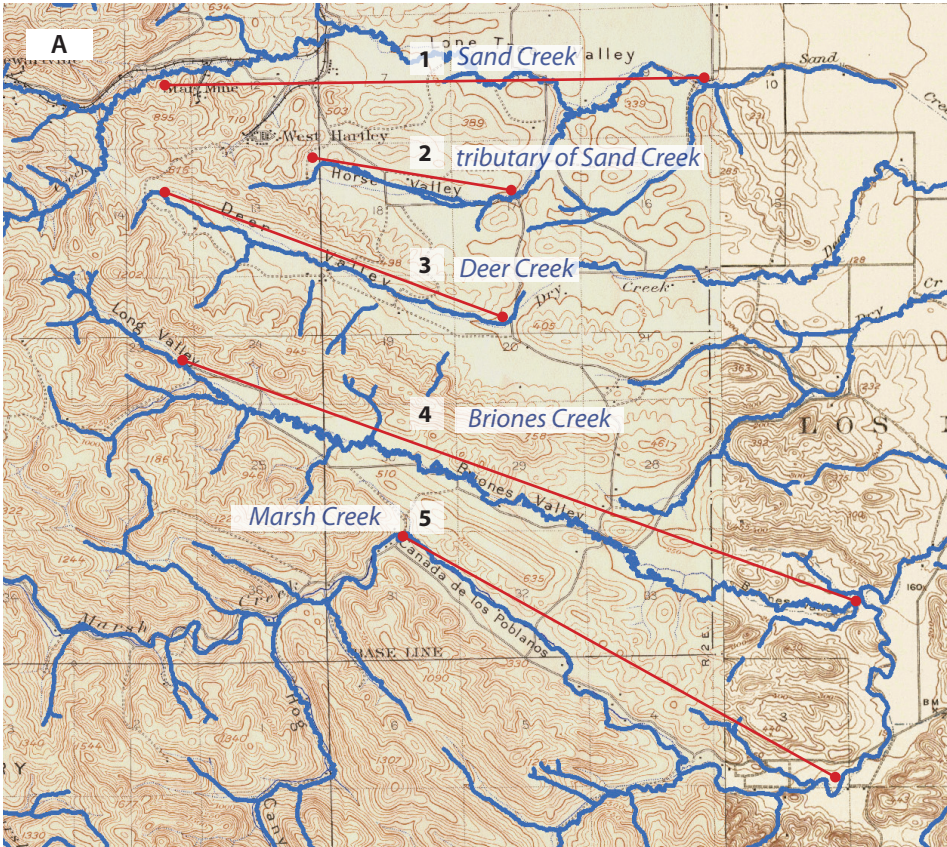


Figure 4.13. Investigation of historical sinuosity. We examined sinuosity for stream reaches running through five parallel valleys. These were sinuous Sand and Briones creeks (1 and 4), and a relatively straight tributary of Sand Creek (through Horse Valley), as well as Deer and Marsh creeks

(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)

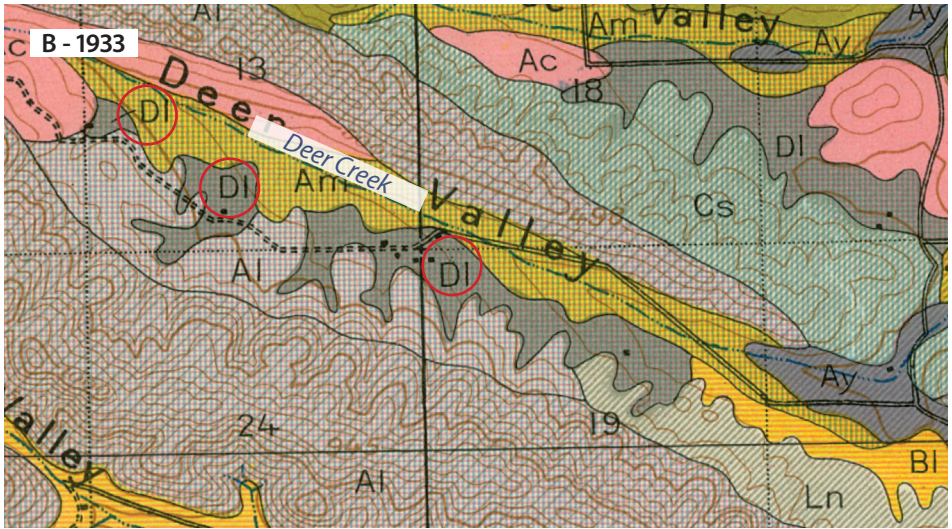
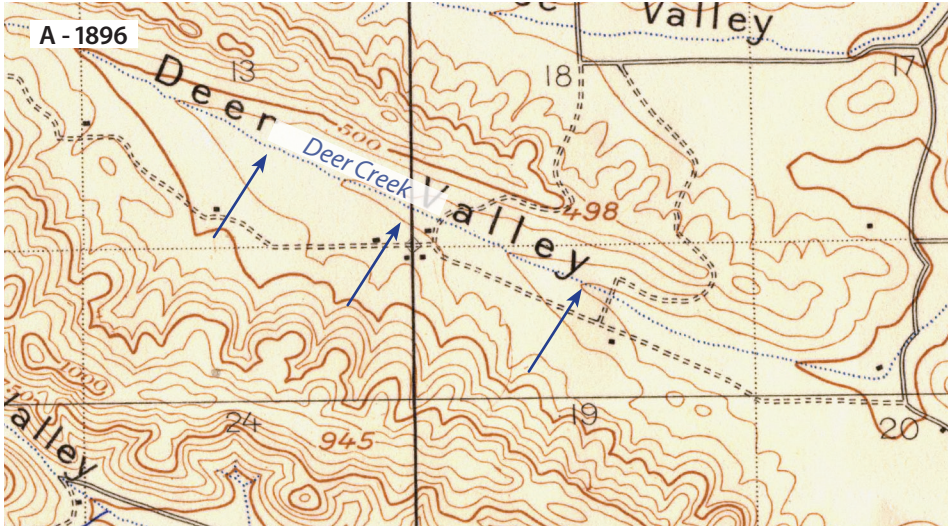


Figure 4.14. Sinuosity of Deer Creek. A) Upper Deer Creek followed a relatively straight course, constrained to the northern edge of its valley. South of the creek, the soil survey (B) shows deposits of Danville clay loam (DI), shown in dark grey. These alluvial deposits, created by small hillside tributaries, 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.

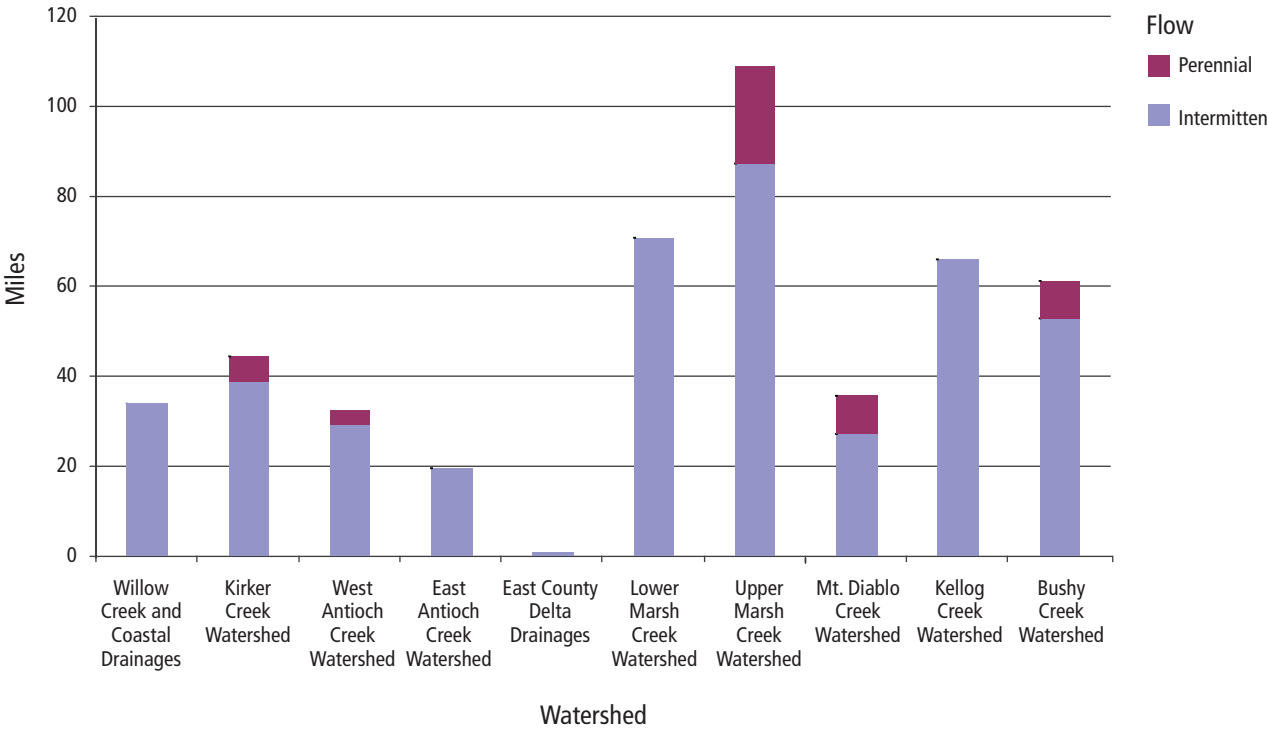
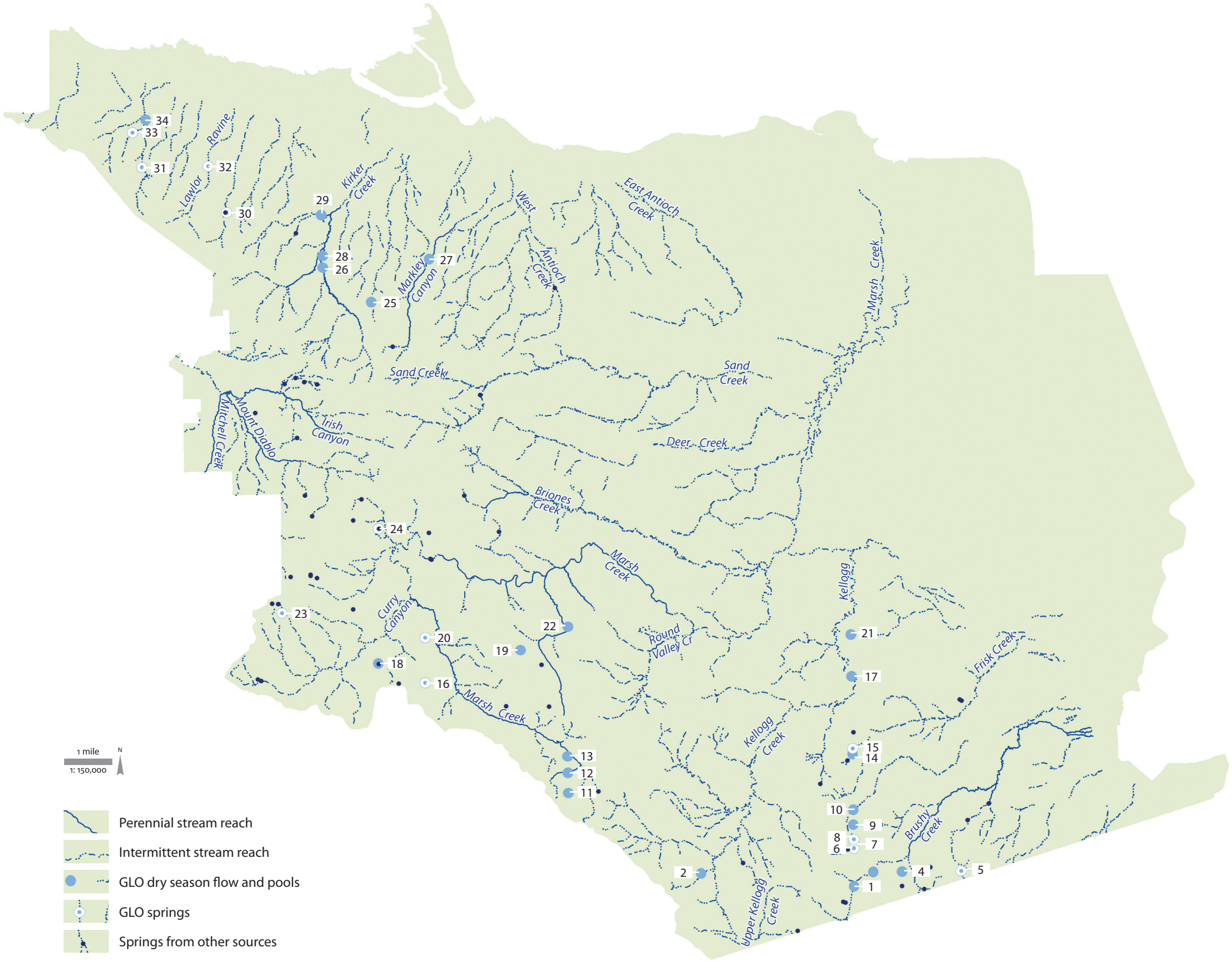


Figure 4.17. Dry season water. The figure below compares USGS and GLO data for perennial and intermittent stream reaches. Reaches mapped as perennial by USGS are coded with a solid blue line, while intermittent reaches are dashed. The table to the right presents all of the GLO data documenting pools, 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 foliated 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.

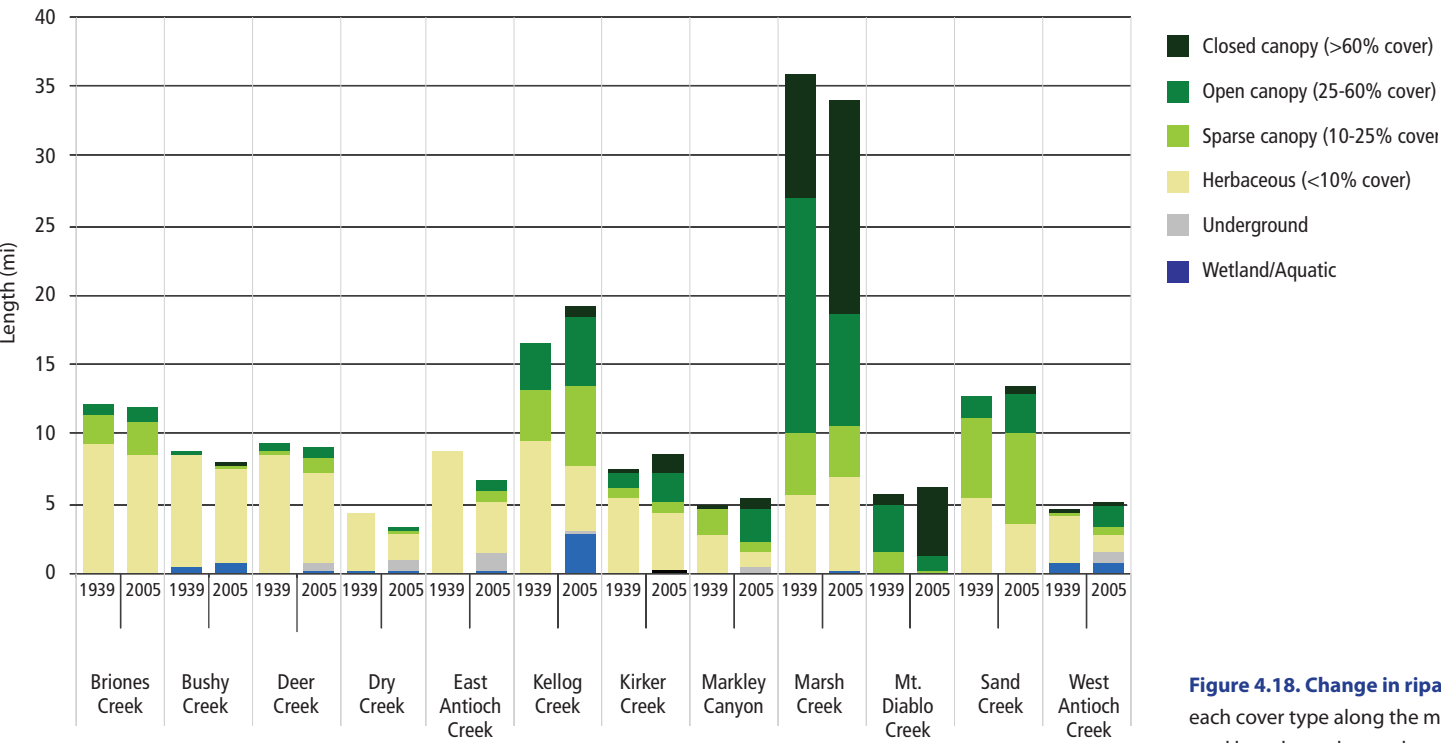


Figure 4.18. Change in riparian cover by creek. This graph compares miles of each cover type along the mainstems of the major creeks of ECCC. Differences in total length are due to changes in the drainage network.

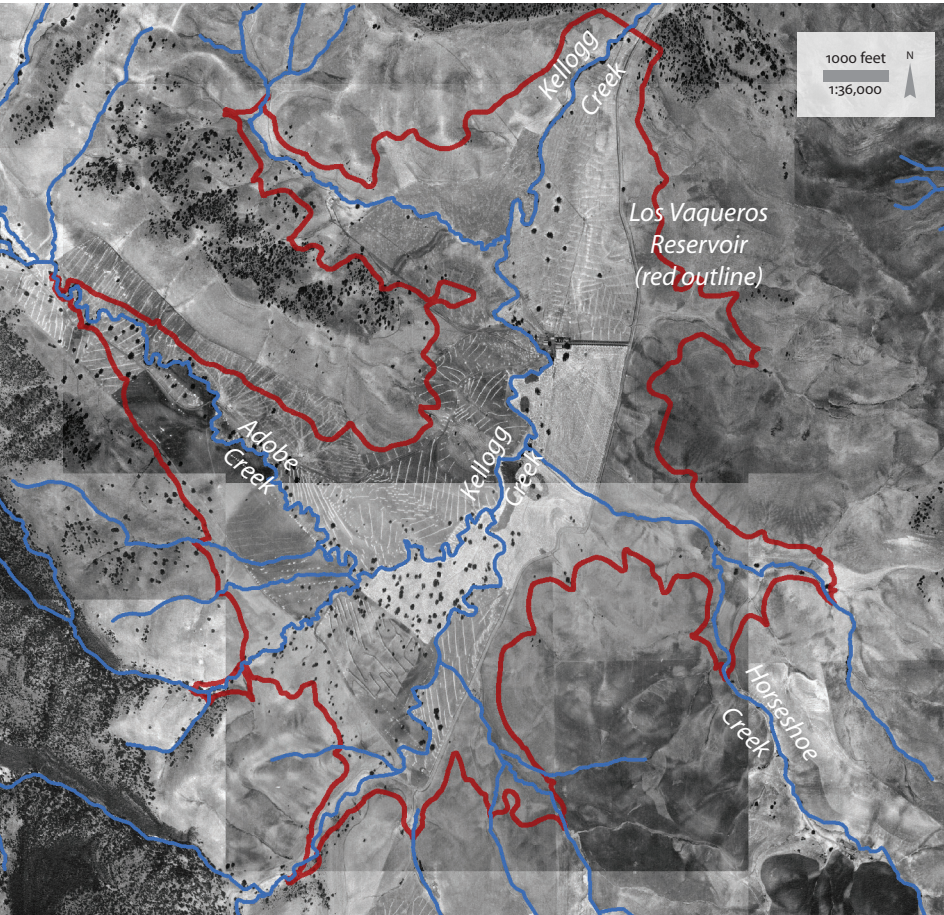


Figure 4.19. Historical riparian cover along Kellogg Creek. Some historical riparian trees have been covered by new wetlands and reservoirs. The creation of Los Vaqueros Reservoir provides the most dramatic example of this. The historical aerial photograph captures the region before the reservoir was 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)

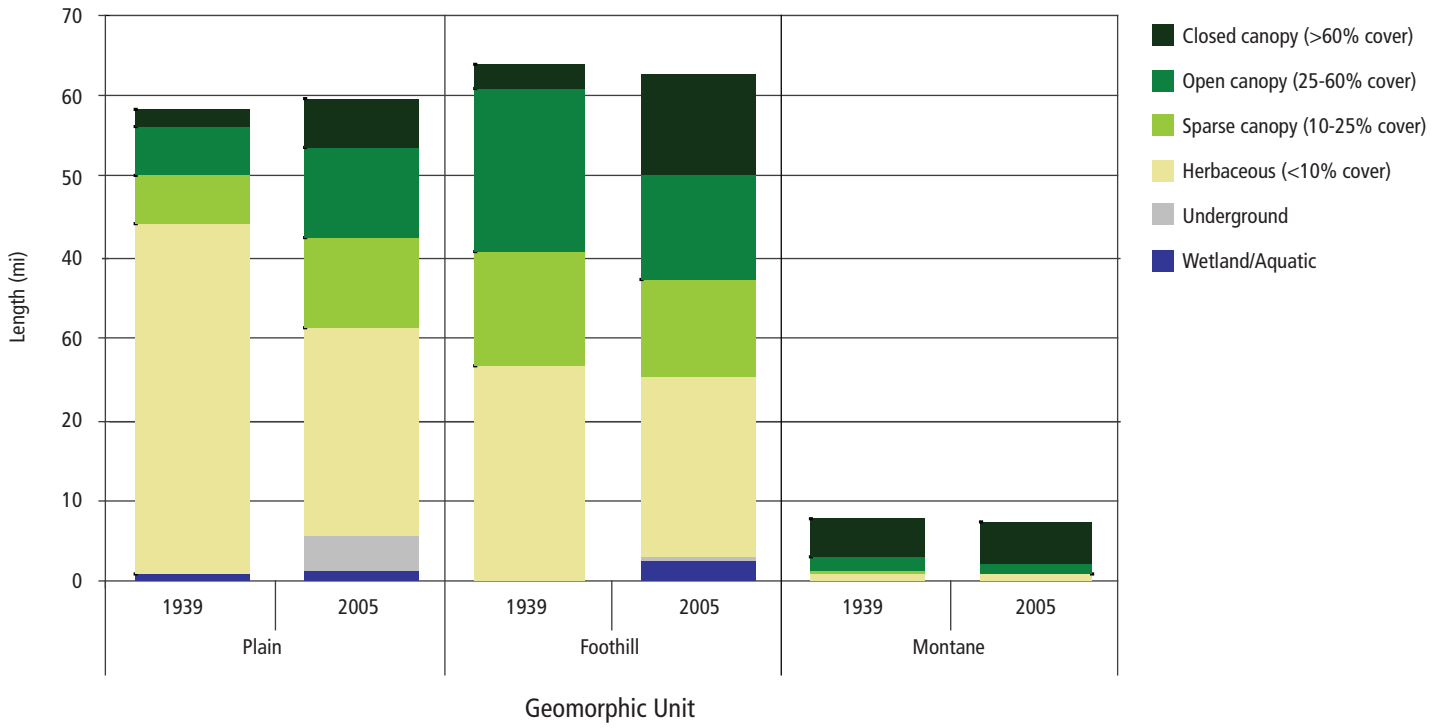


Figure 4.20. Change in riparian cover by geomorphic unit. (above) Each column shows the summed length of each riparian cover type along major reaches in ECCC divided by geomorphic unit. The geomorphic units are plain (<200 ft), foothill (200-900 ft), and montane (>900 ft). Again, differences in total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

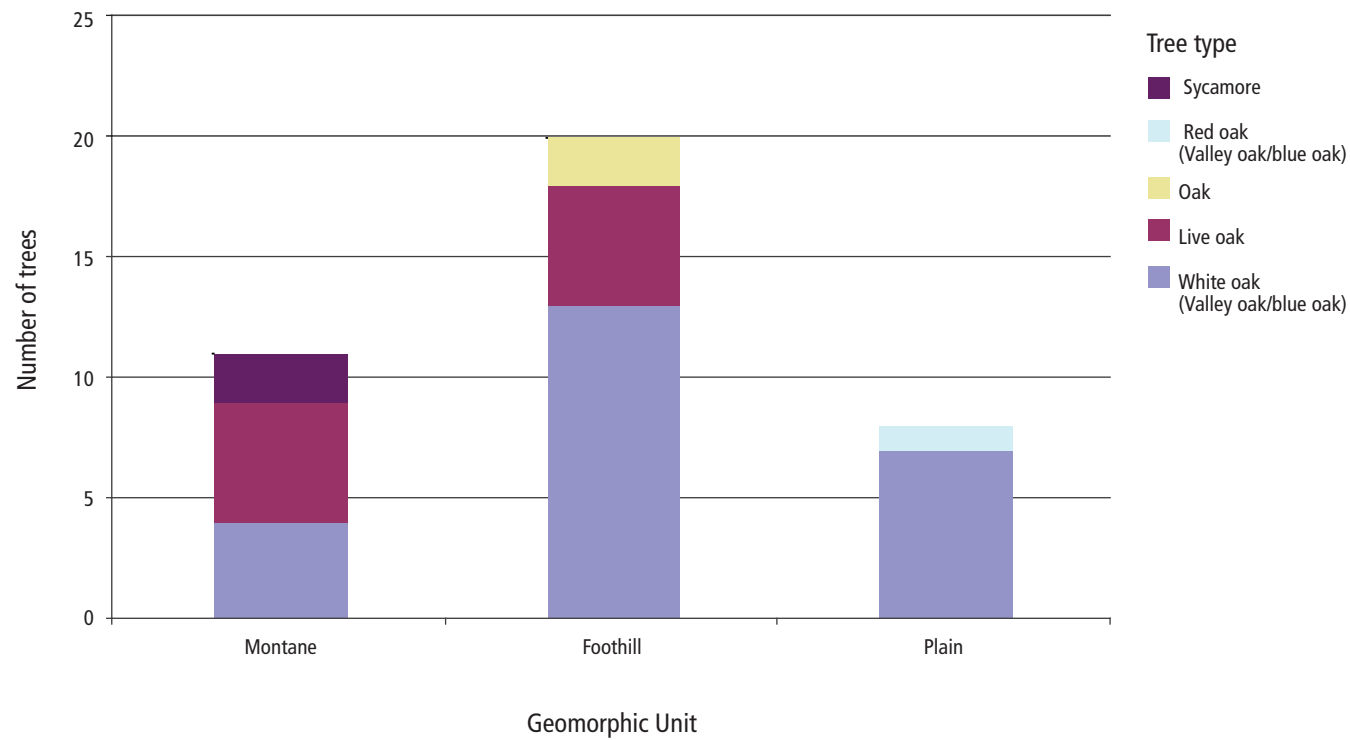


Figure 4.22. GLO riparian trees by geomorphic unit. (above) These data show bearing trees recorded by the GLO survey from the 1850s-1870s. While ‘white oaks’ (likely blue or valley oaks) were distributed on creeks throughout the study area, sycamores and live oaks were found only in the upper, more hilly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

Habitats	Example(s) (with relevant illustrations)	Probable Native Fish Assemblage ¹	Notes on Habitat Use
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>i.e.</i> , 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>i.e.</i> , 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.

¹The 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 vary 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 <i>Acipenser</i> 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 <i>Gila crassicauda</i> 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)
<i>Lavinia exilicauda</i> 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)
<i>Lavinia symmetricus</i> 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 <i>et al.</i> 1996) Brushy Creek, between ponds 2 and 3 (1997)(EBRPD 1997)
<i>Orthodon microlepidotus</i> 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)
<i>Pogonichthys macrolepidotus</i> 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)
<i>Mylopharodon conocephalus</i> 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)
<i>Ptychocheilus grandis</i> 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 <i>Catostomus occidentalis</i> 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 <i>Oncorhynchus mykiss</i> rainbow trout/steelhead	OBF-SD	M, AND, FWR	U	MR, TC	“Back of Martinez, toward the foot of Monte Diablo”, as <i>Salmo rivularis</i> , 16 April 1855 (Ayres 1855)(possibly Mount Diablo Creek watershed). Mitchell Canyon Creek, April 1985 (Leidy, Becker and Harvey 2005).
<i>Oncorhynchus tshawytscha</i> 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 <i>et al.</i> 1996) Marsh Creek, various locations below drop structure (2001-2007)(Puckett pers. comm.)
GASTEROSTEIDAE/ STICKLEBACKS <i>Gasterosteus aculeatus</i> 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 <i>Cottus asper</i> 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 <i>Archoplites interruptus</i> 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 <i>Hysterocarpus traskii</i> 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 utilizes remnant 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 (*Branchinecta 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)



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

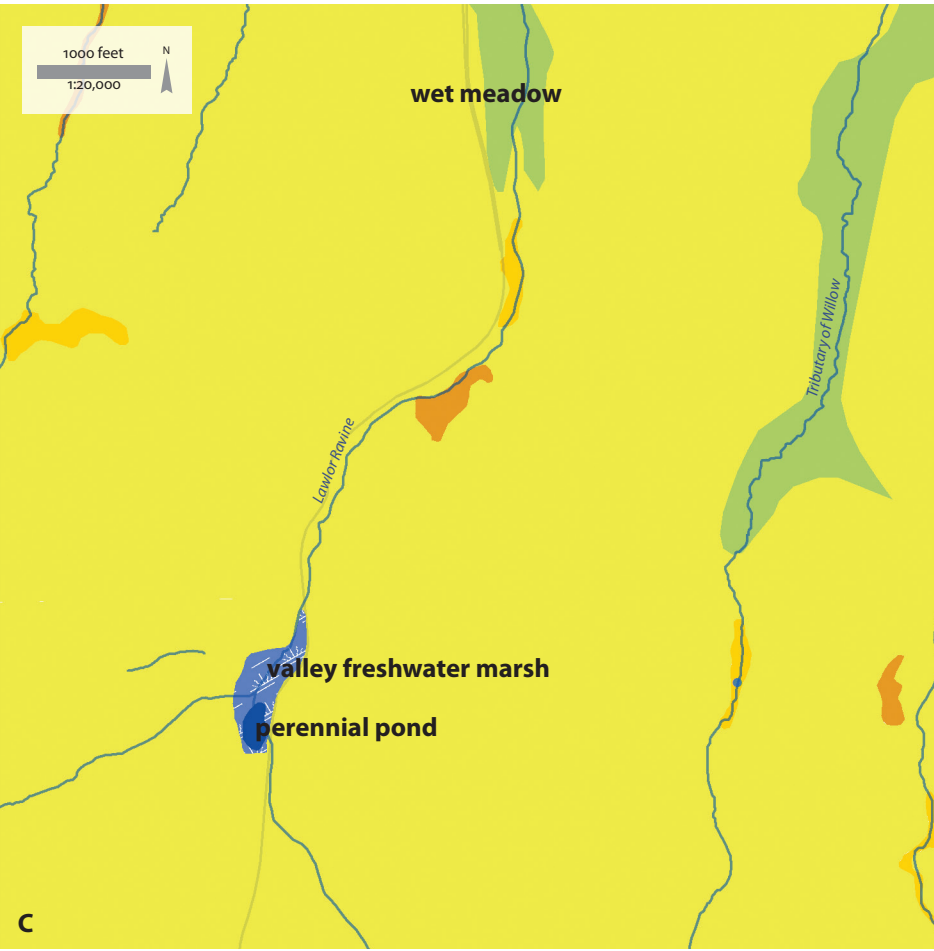
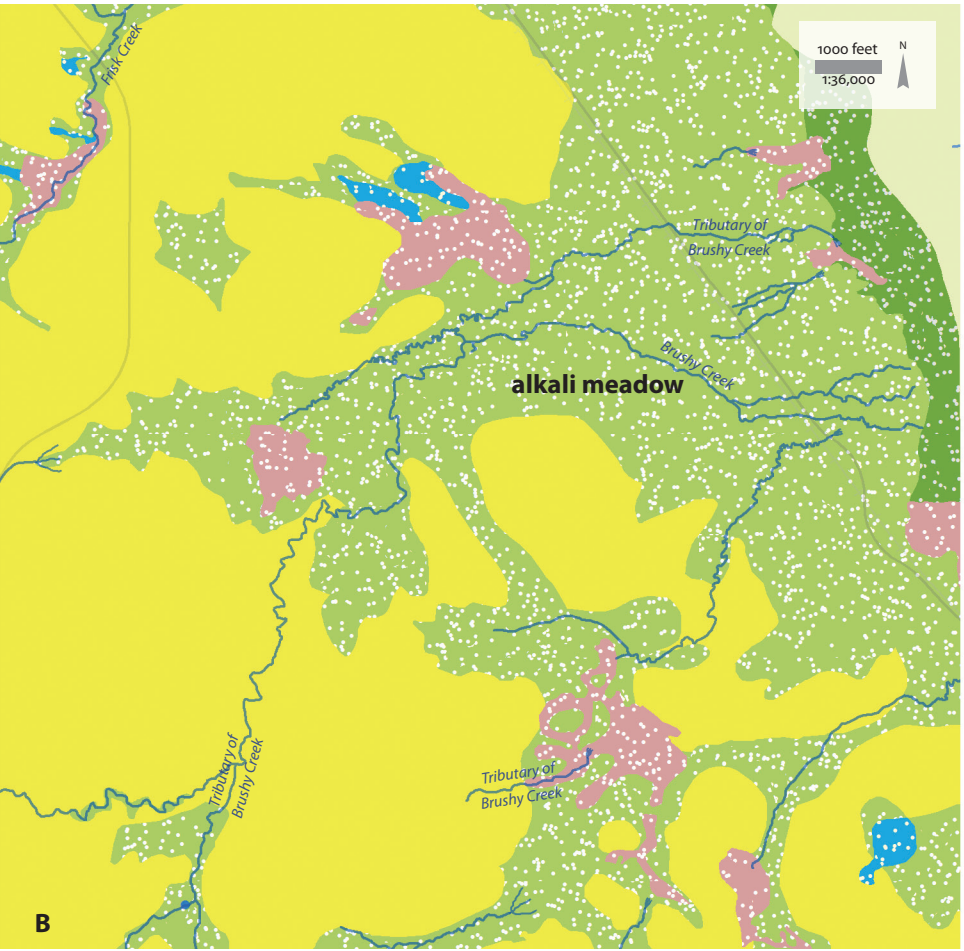
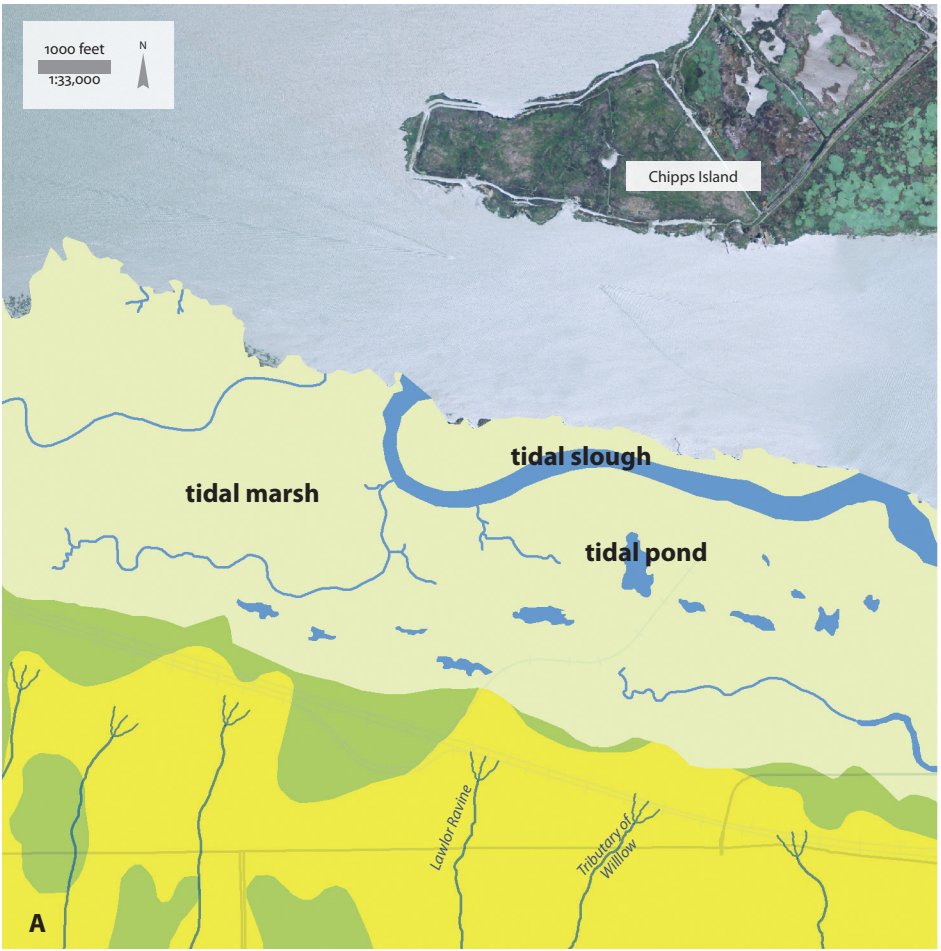
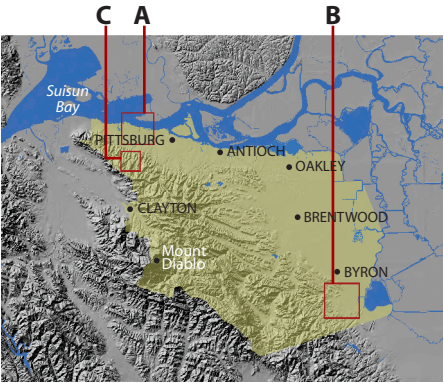
the 1880s T-sheets because of their higher spatial resolution. We used details from the 1866 T-sheet in cases where the 1880s maps showed signs of recent modification.

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 5.2. 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.



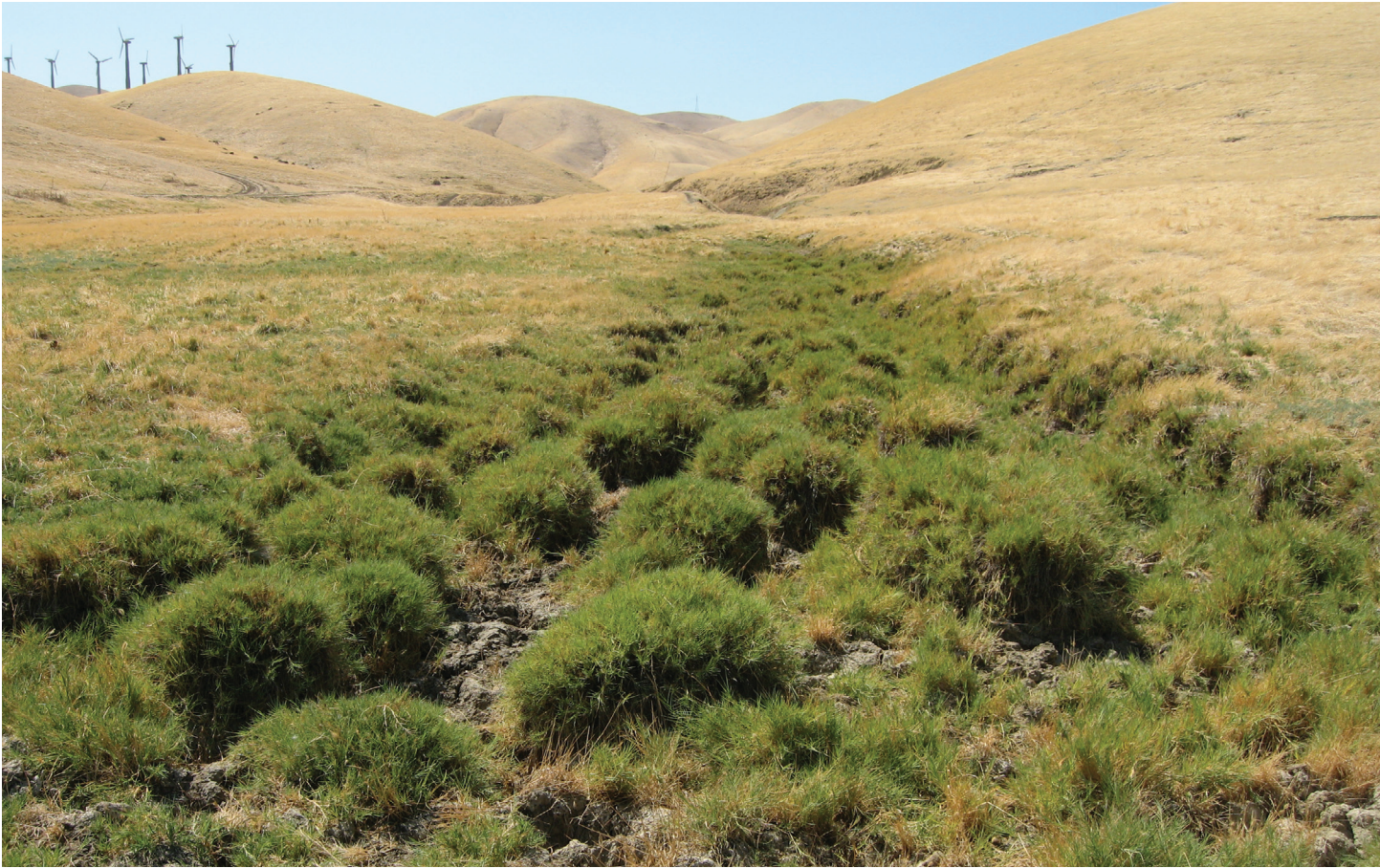


Figure 5.3. Hummocky saltgrass. This alkaline meadow habitat occurs today along a tributary to Frisk Creek in southeastern Contra Costa. (Photo by Abigail Fateman, CCC)

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).

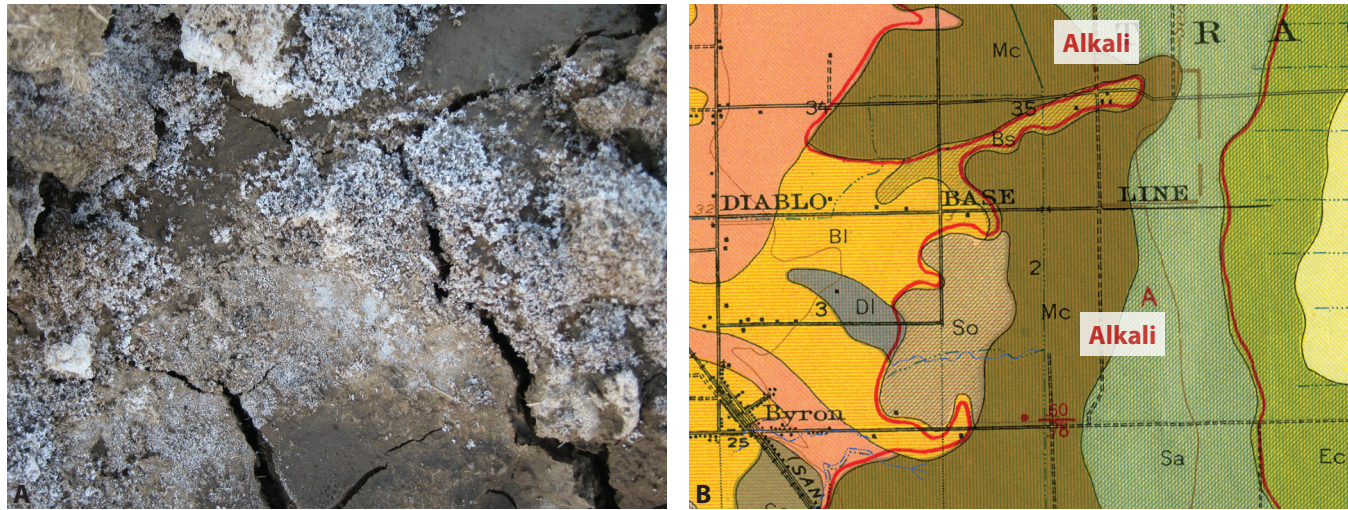


Figure 5.4. Alkali indications. (A) A crust of salt and other minerals is left on the cracked ground after pooled water evaporates near Byron. (B) The 1933 USDA soil map delineates alkali areas using a red line - areas in the center of the image between the two red lines were measured with alkali levels 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 aerals 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.

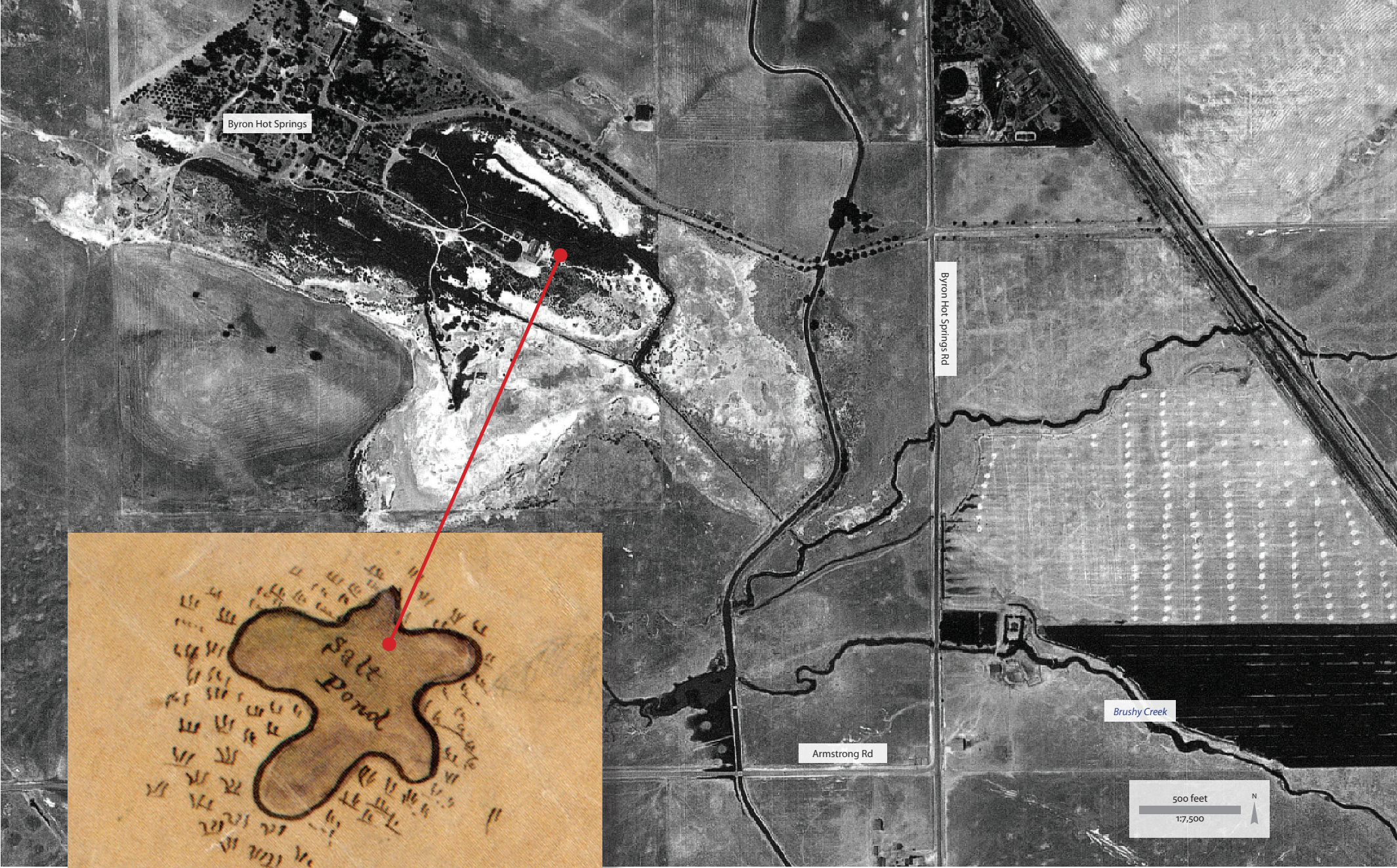


Figure 5.5. Depictions of alkali habitats in 1853.

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 maritimumus*), 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.

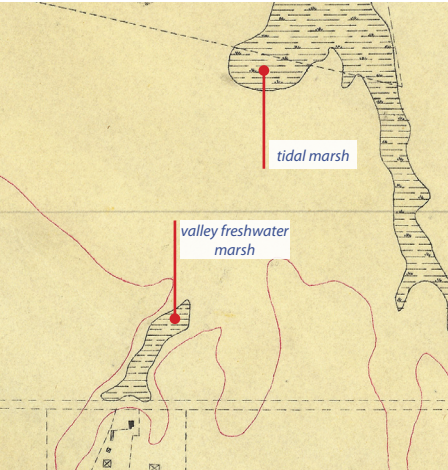
To identify perennial wetland features, including freshwater marshes, ponds, and springs, we relied on aerial imagery and early mapping. Aerial imagery from 1939 exhibited distinct wetland signatures in a number of places throughout the study area. As these images were taken during the summer of a dry 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.

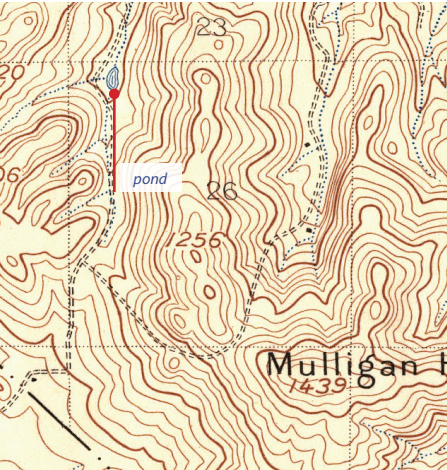
Figure 5.6. Historical evidence for palustrine wetlands. These images show a variety of symbols used to indicate wetlands. From left to right: a pond near Kellogg Creek (A); tidal marsh and valley freshwater marsh near Antioch (B); a pond south of SR 4 near Bailey Road and the CNWS (C); and a dark area 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

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

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

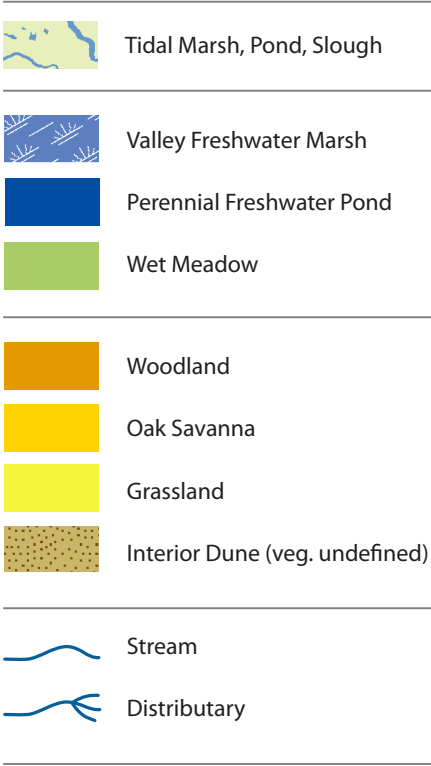
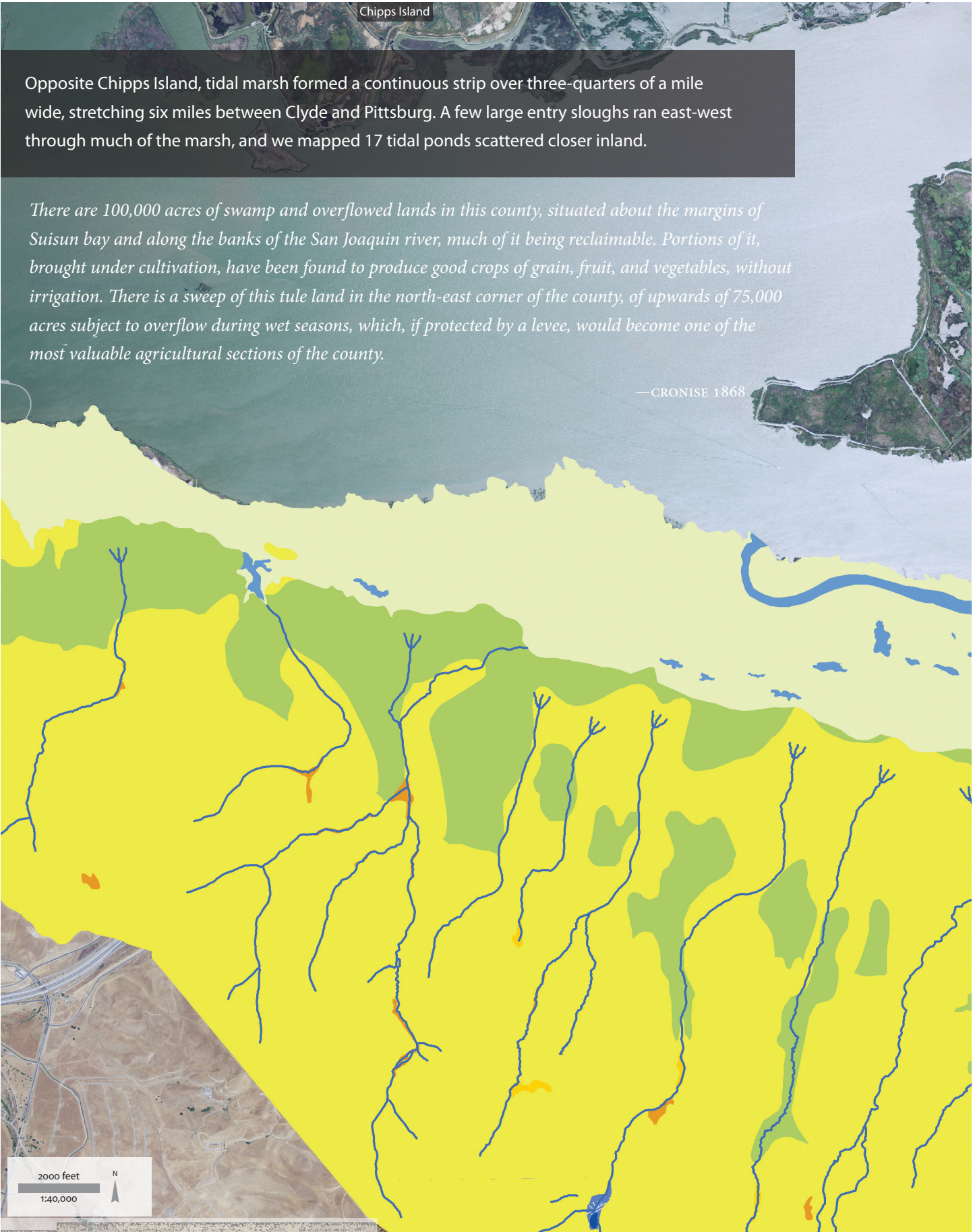
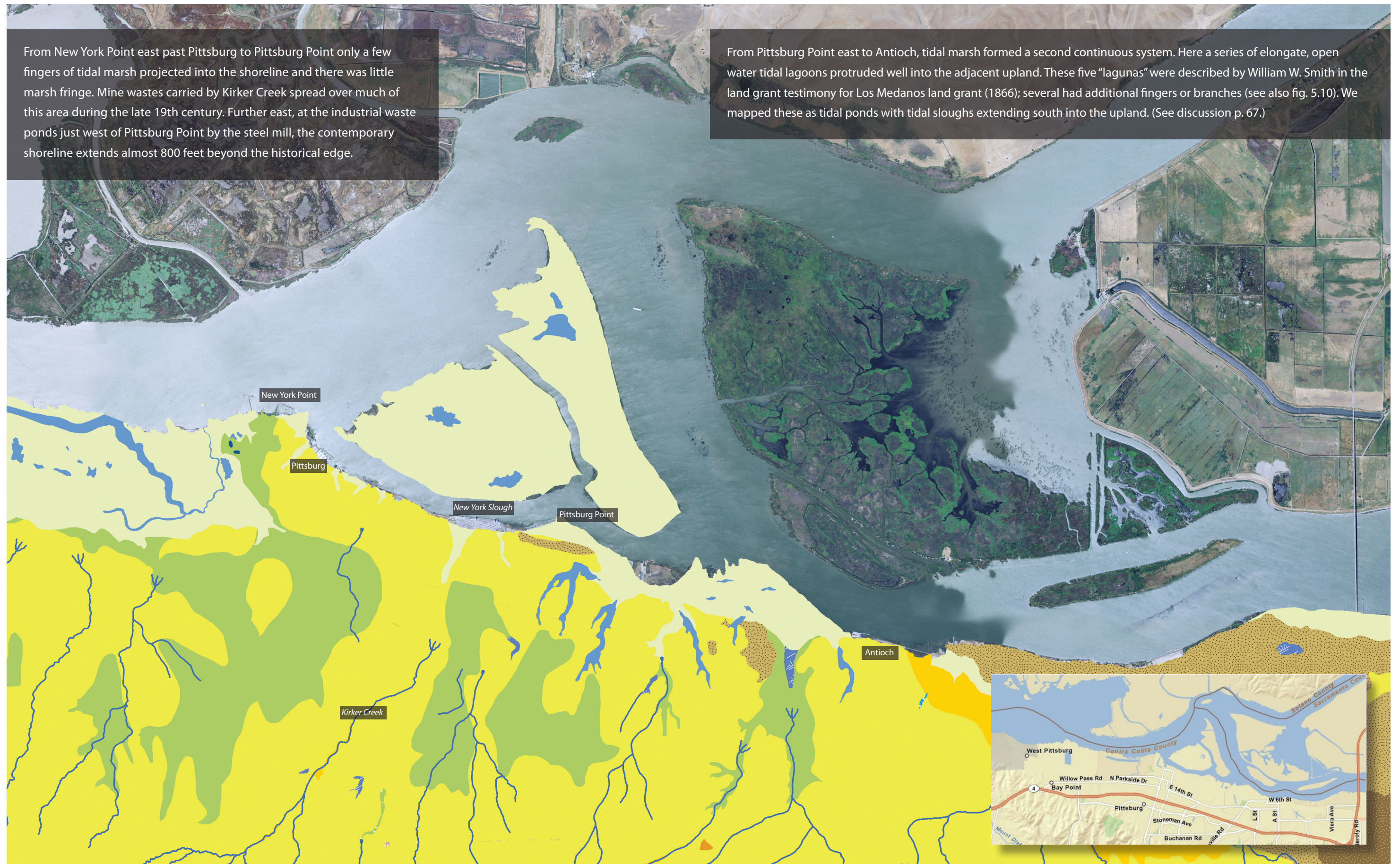


Figure 5.7. Historical tidal marsh – western portion. Tidal marsh shown in pale green, sloughs in light blue. (Background USDA 2009, courtesy of NAIP)



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

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

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).

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

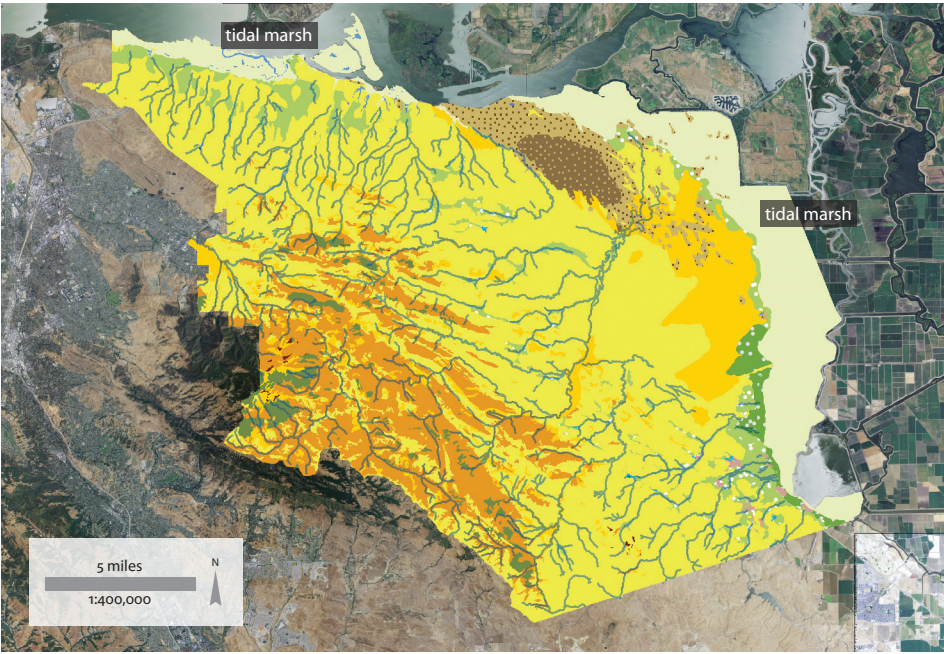
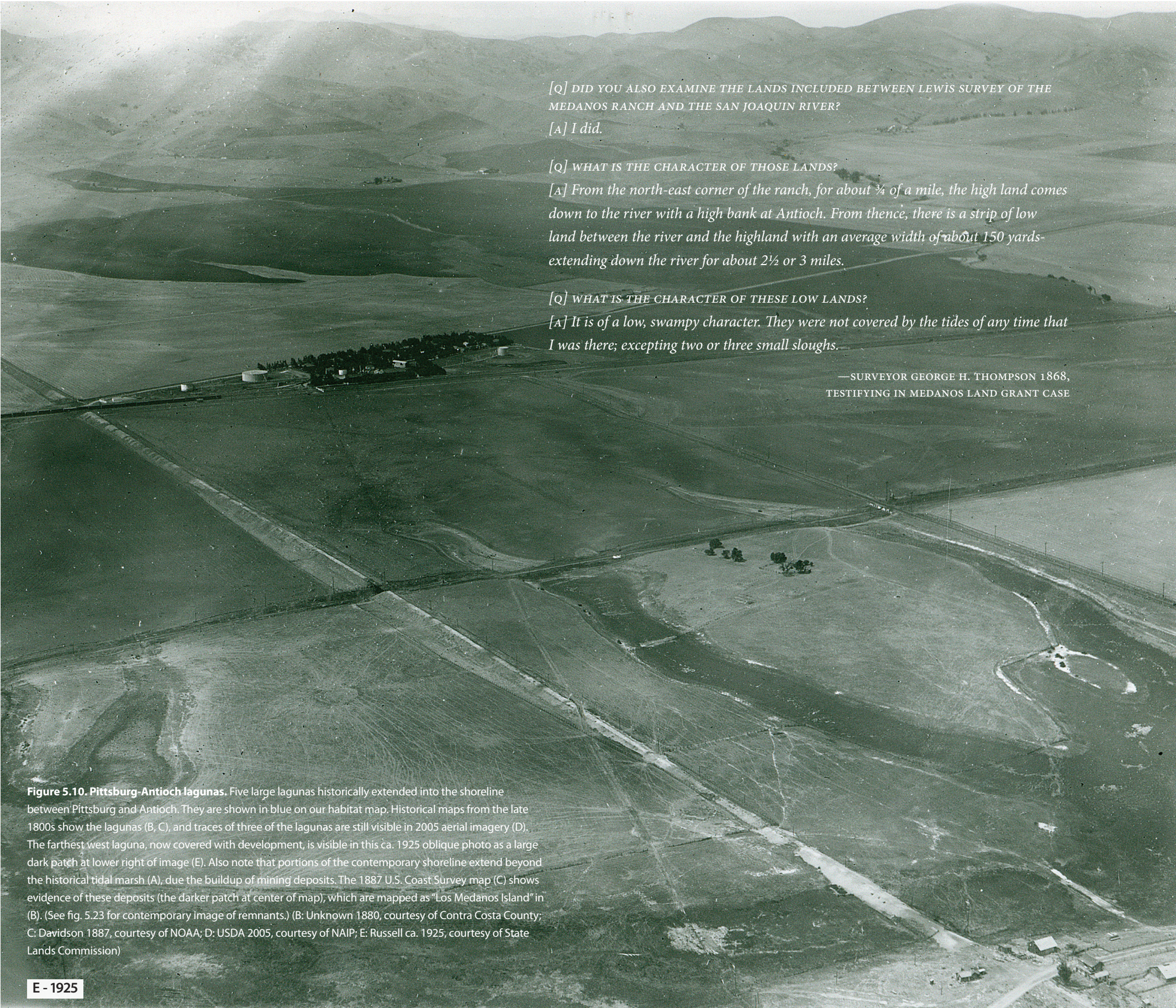
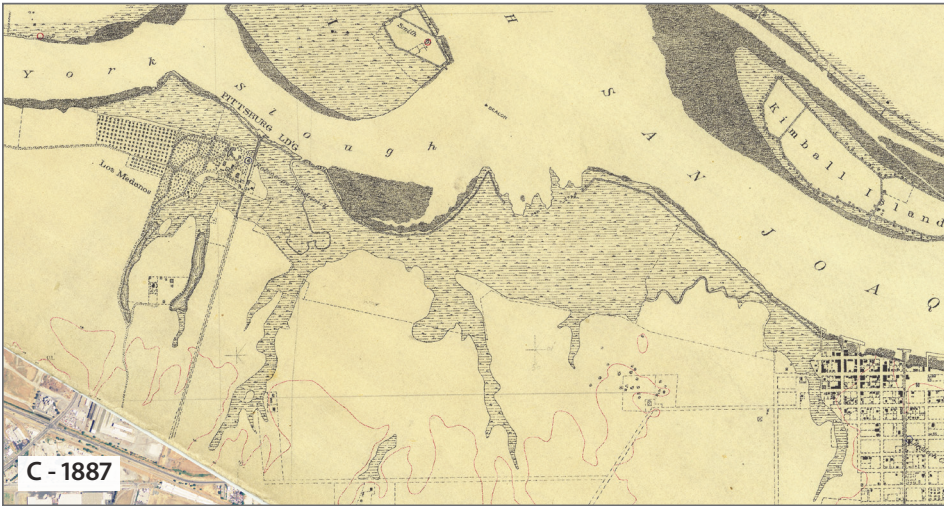
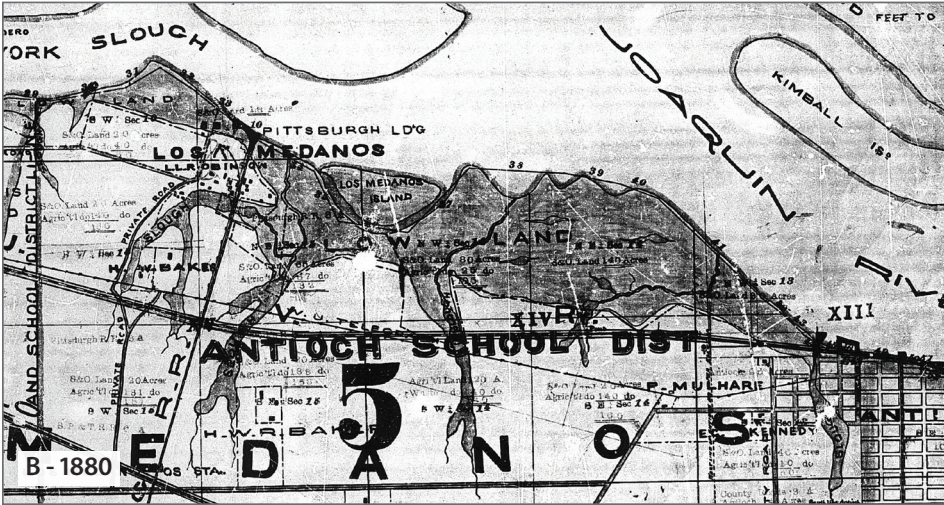


Figure 5.8. Historical tidal marsh. Tidal marsh (pale green) stretched east and south along the border of ECCC to join with the marshes of the Sacramento-San Joaquin Delta. Much of the eastern body of tidal marsh has since been reclaimed and drained – we measure a loss of at least 14,000 acres out of 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

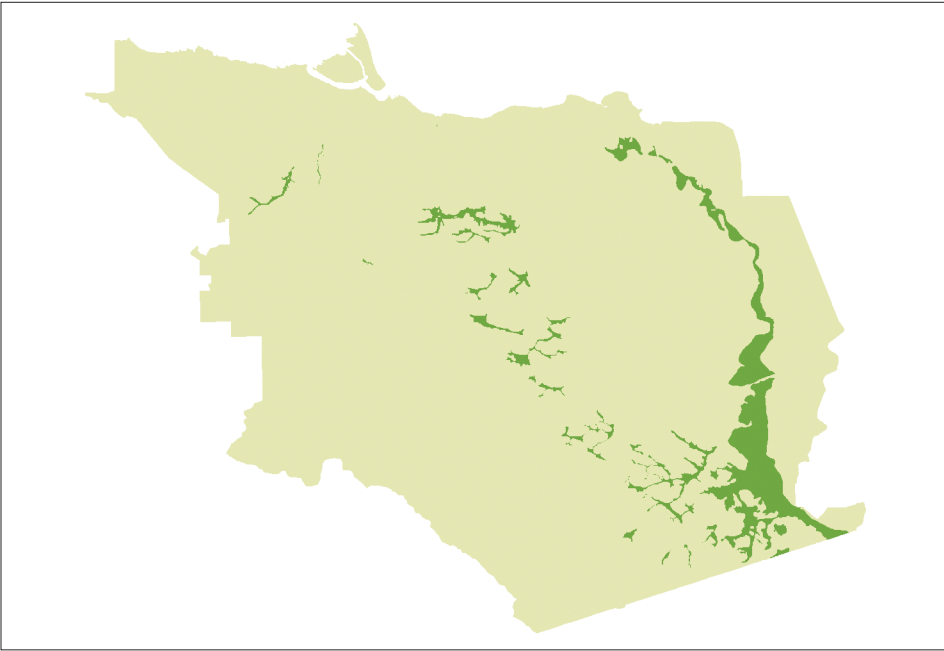


Figure 5.11. Historical alkali extent. The dark green polygons show the alkali habitats of ECCC, which include perennial alkali pond, alkali marsh, alkali flat, alkali sink scrub, and alkali meadow.

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, CNDDDB 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).

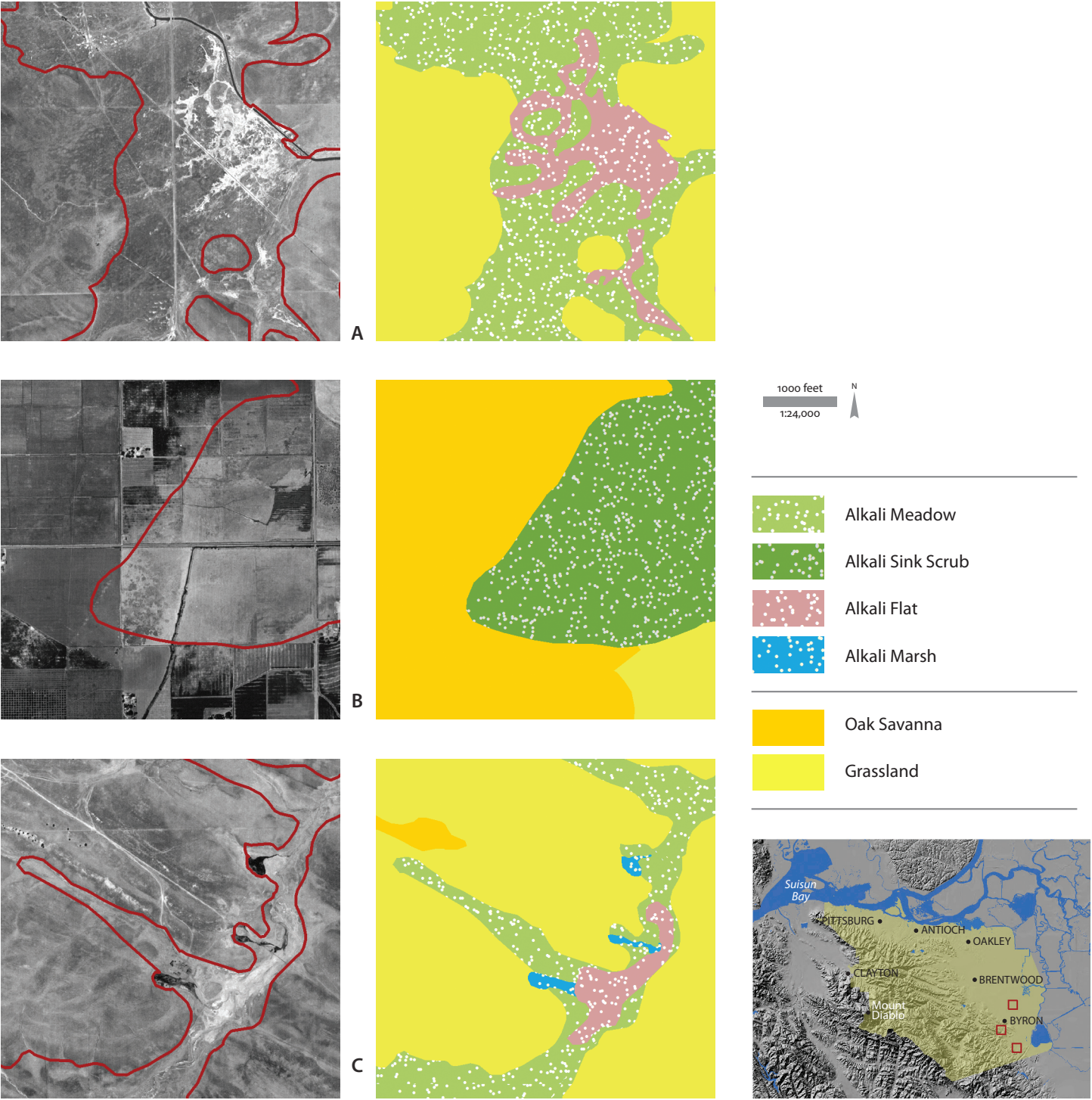


Figure 5.13. Alkali habitat signatures in historical aeriels. Red lines on the historical aeriels at left trace the extent of historical alkali habitats; these habitats are shown as mapped at right. In the first set of images (A), the bare scalded alkali flat contrasts with the surrounding grasslands 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)

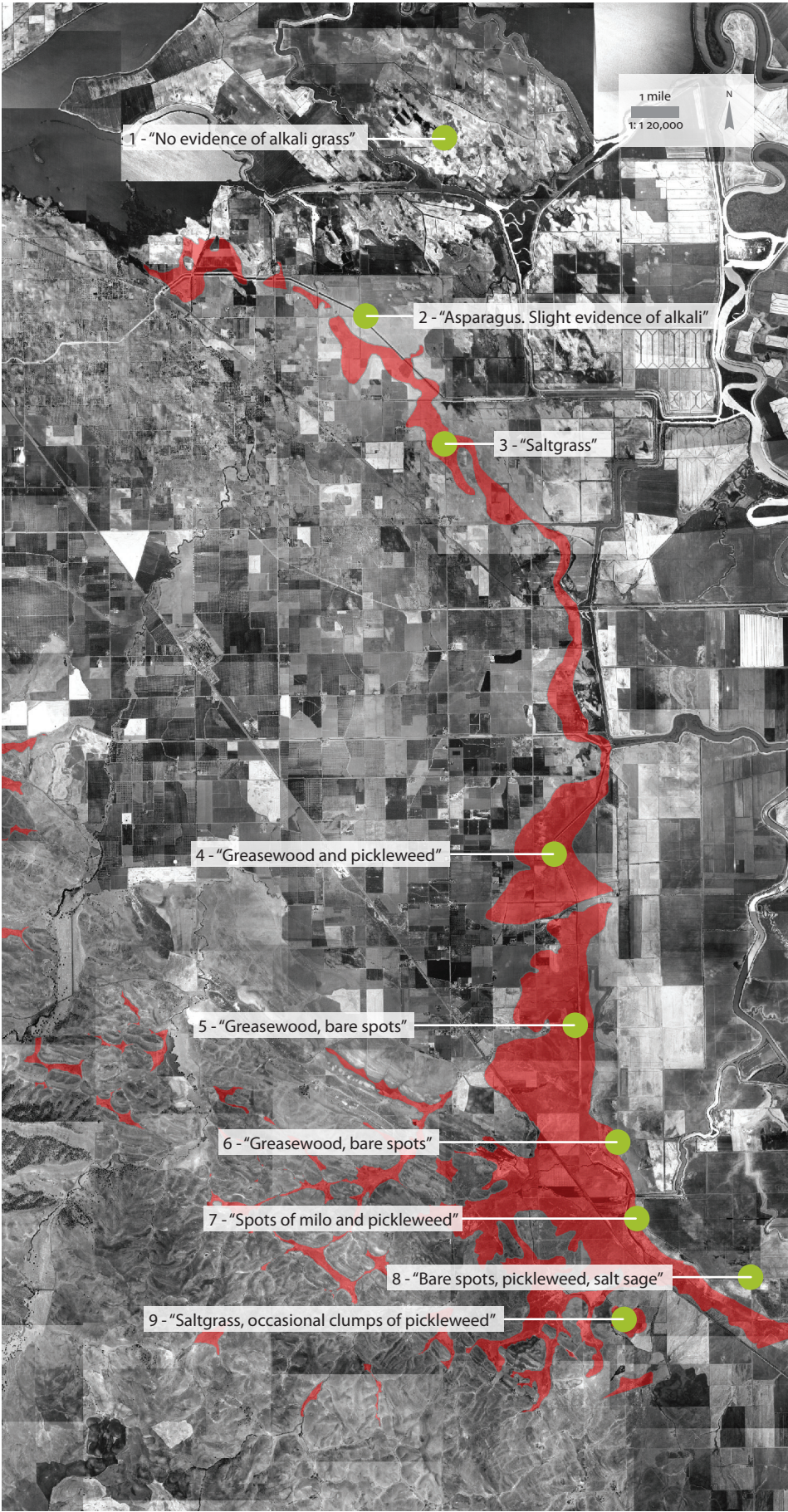


Figure 5.14. Alkali vegetation and soil samples. The 1939 soil survey report included an analysis of salt content at nine points in “salt-affected soils” along the eastern border of the county, which are excerpted at left. All nine of these points fall within alkali habitats (shown in red) or the historical 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)



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).

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 <i>Distichlis spicata</i>)	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 = <i>Distichlis spicata</i>	Clay / A Clay / B Clay / C	.225 / A .775 / B .31 / C	.44
4	"Greasewood and pickleweed"	Greasewood (probably iodine bush or <i>Allenrolfea occidentalis</i>) Pickleweed = <i>Salicornia</i>	Clay / A Clay / B Silty Clay Loam / C	.075 / A .60 / B -- / C	.34
5	"Greasewood, bare spots"	Greasewood (probably iodine bush or <i>Allenrolfea occidentalis</i>)	Loam / A Clay / B Clay Loam / C	.60 / A .95 / B -- / C	.78
6	"Greasewood, bare spots"	Greasewood (probably iodine bush or <i>Allenrolfea occidentalis</i>)	Loam / A Clay / B Clay / C	1.16 / A 1.18 / B 1.14 / C	1.16
7	"Spots of milo and pickleweed"	Milo (<i>Sorghum</i> , cultivated crop) Pickleweed = <i>Salicornia</i>	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 = <i>Salicornia</i> Salt sage = <i>Atriplex</i>	Clay / A Clay / B Clay / C	.88 / A 1.16 / B .55 / C	.86
9	"Saltgrass, occasional clumps of pickleweed"	Saltgrass = <i>Distichlis spicata</i> Pickleweed = <i>Salicornia</i>	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).

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)

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).

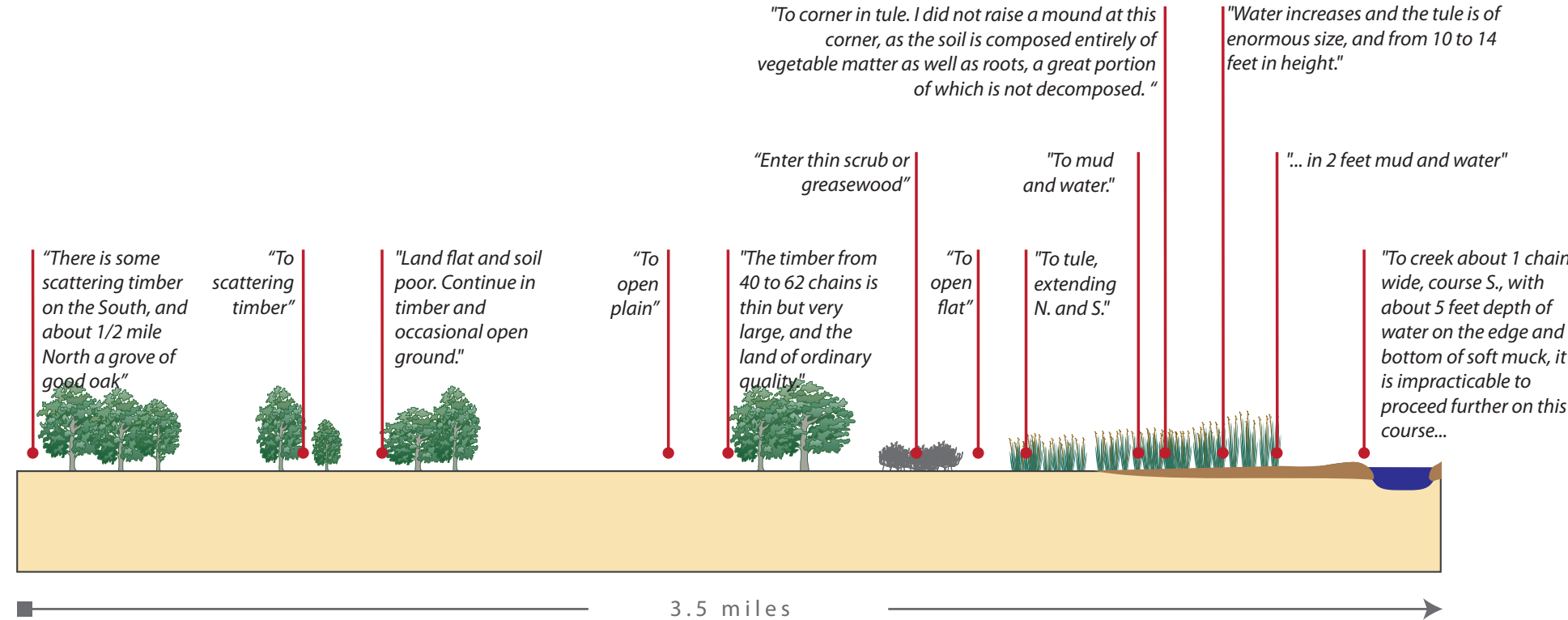
We mapped 290 acres of alkali flats, all concentrated in the southeastern portion of the study area. These were areas that we could identify from the historical soils map and 1939 aerial, some of which had been partially covered or developed by

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 CNDDDB records only four occurrences, including the area around Byron (CNDDDB 2010).



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.

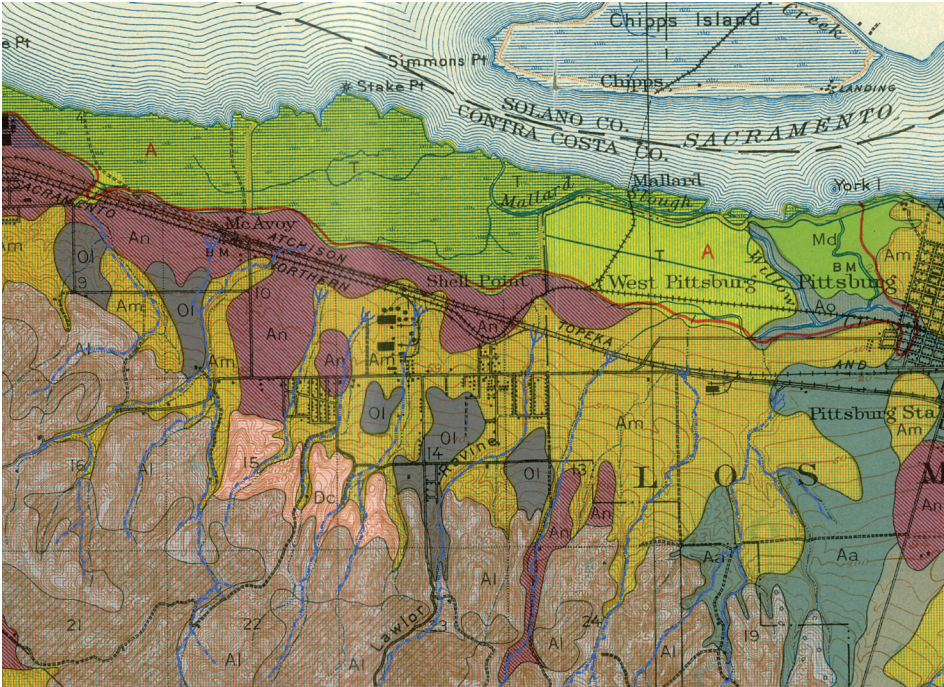


Figure 5.16. Wet soils on the historical soil survey helped us identify potential wet meadows. This portion of the 1933 soil survey just west of Pittsburg shows several wet soils, including Antioch loam (An, purple), Olcott loam (Ol, dark blue), and Ambrose adobe clay (Aa, lighter blue), all of which 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)

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 5.17. 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)

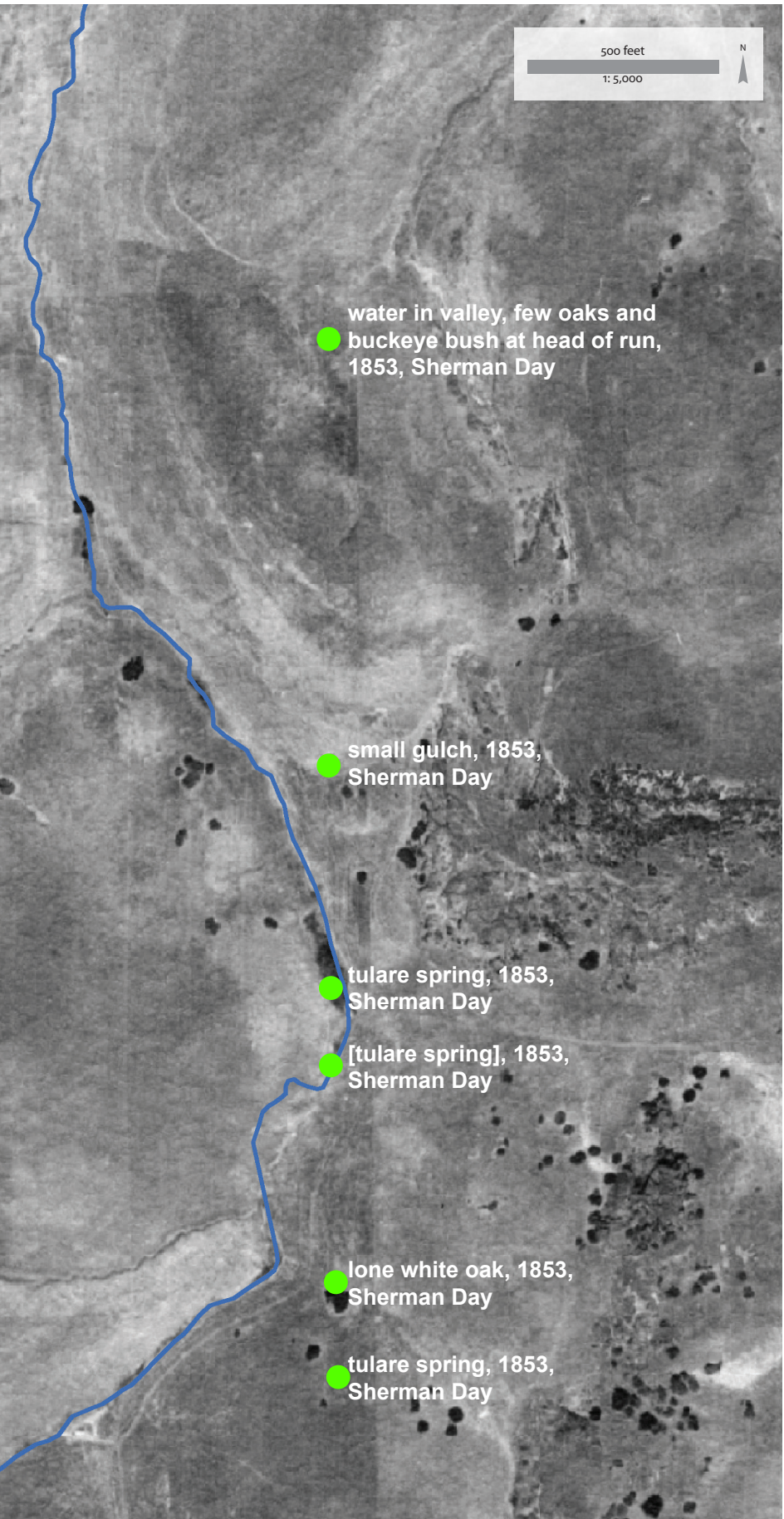
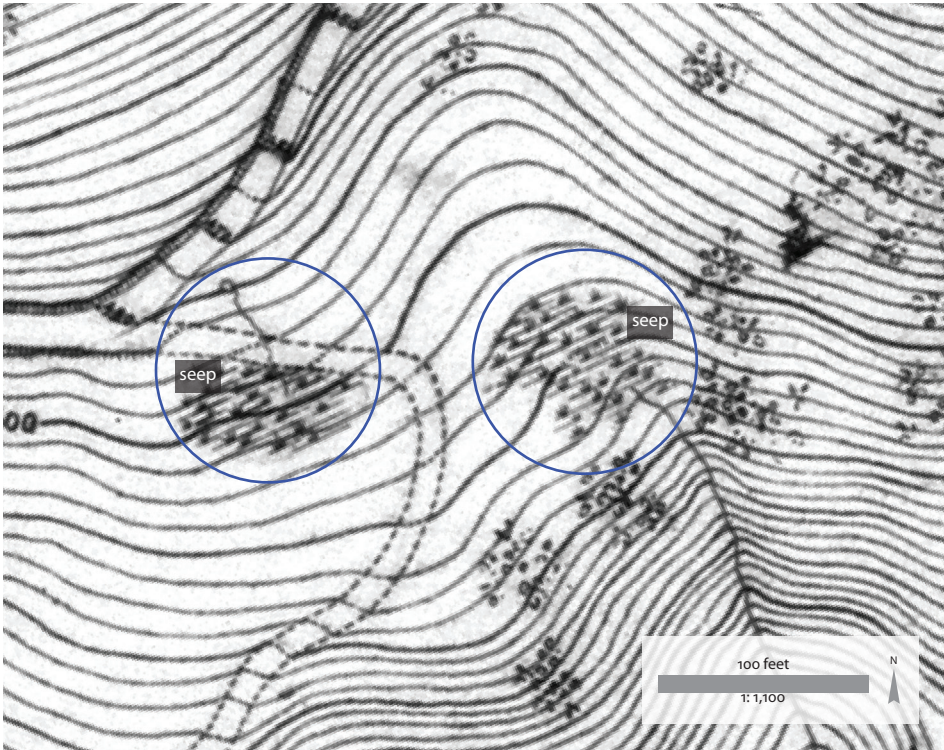




Figure 5.18. Seeps near Mount Diablo. This 1880 map near the peak of Mount Diablo shows small patches of marsh (indicated by the shaded patches) supported by seeps (low-flow springs). Both seep-wetland complexes shown here measure less than a tenth of an acre. At bottom, image of Mount Diablo. (Davidson 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 to the area of contemporary wetland cover.

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

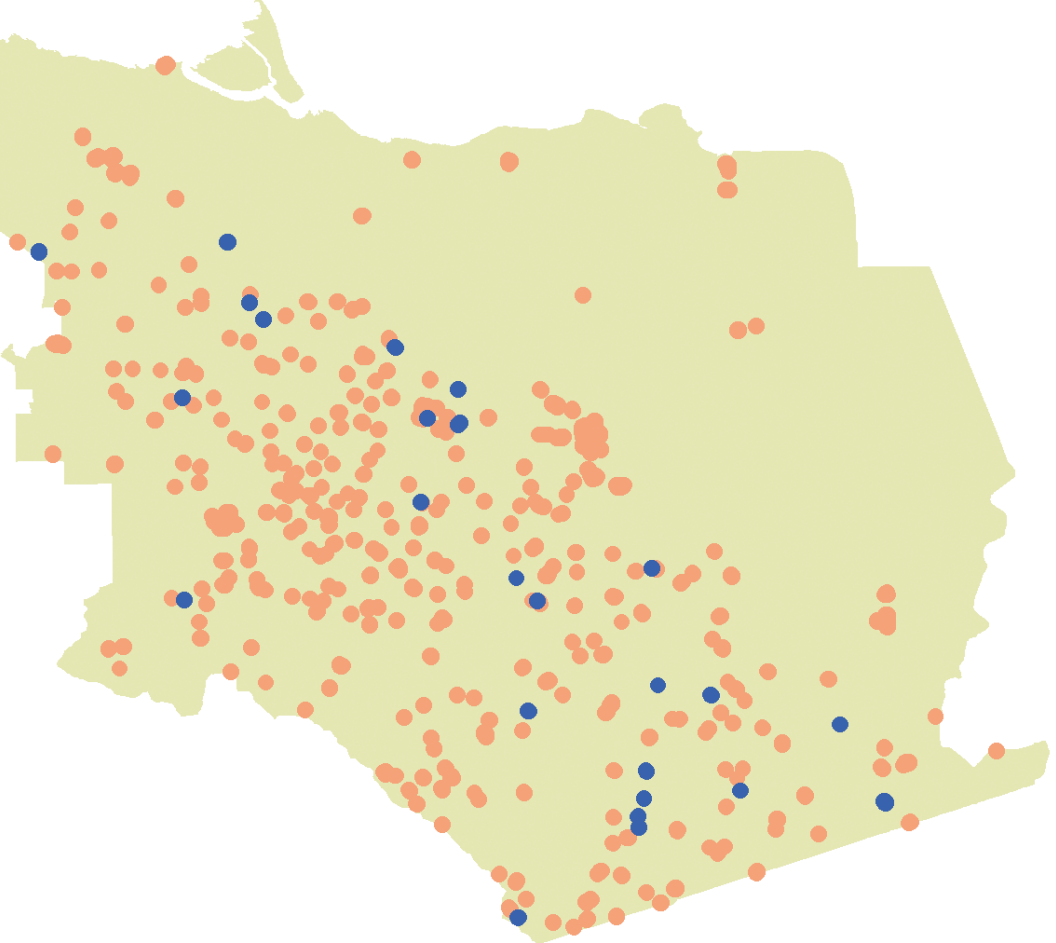
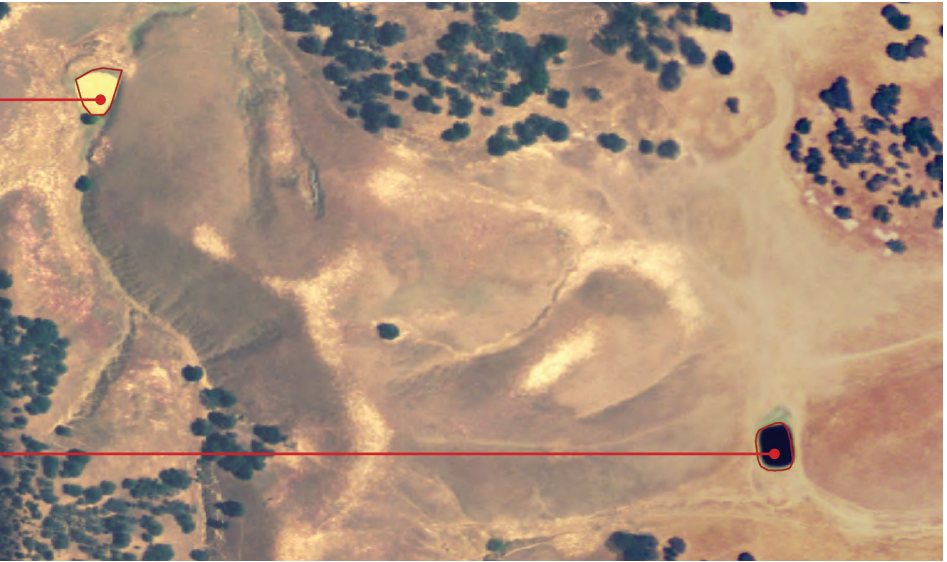
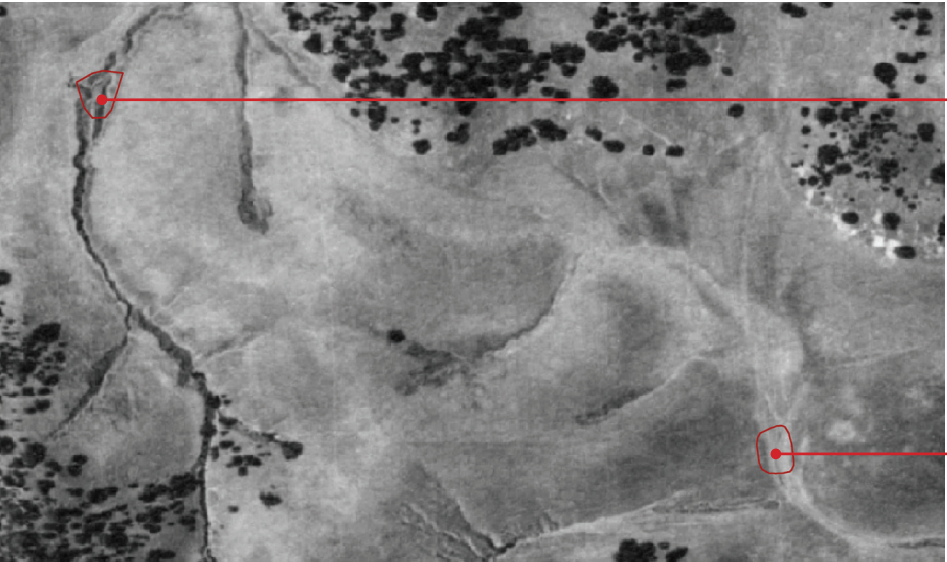


Figure 5.19. Stock pond distribution: 1939 and 2005. We checked for each pond mapped by the HCP in the 2005 and 1939 aerial photos. The diagram above shows ponds that were visible in the aerials only in 2005 (in red) and both in 2005 and 1939 (in blue). Stock ponds in the montane and foothill regions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



wetland along a creek (at top), and a stock pond in 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.

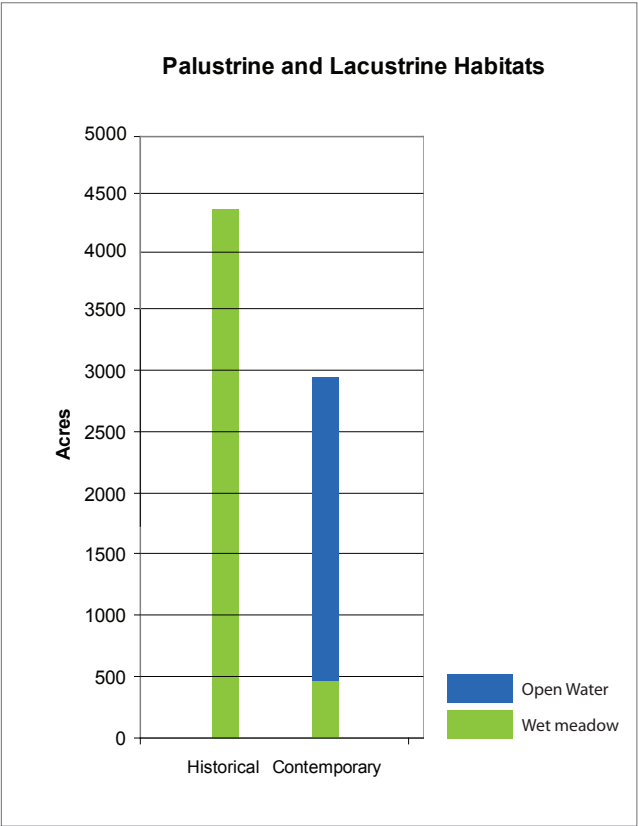
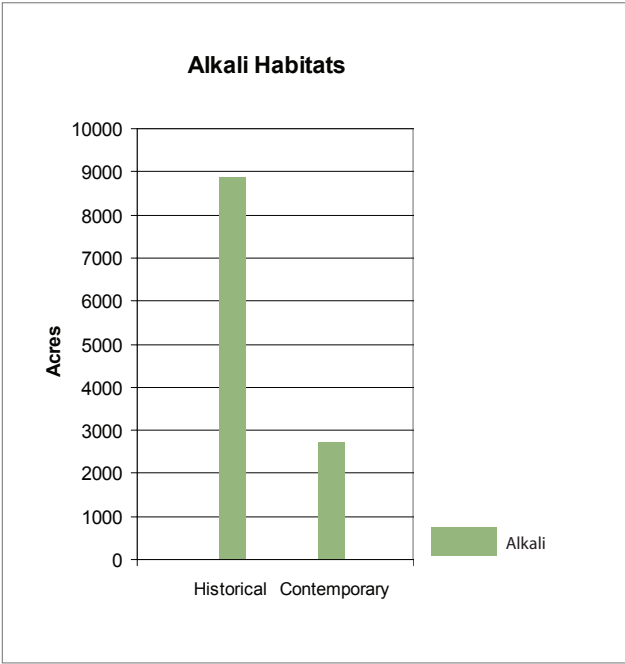
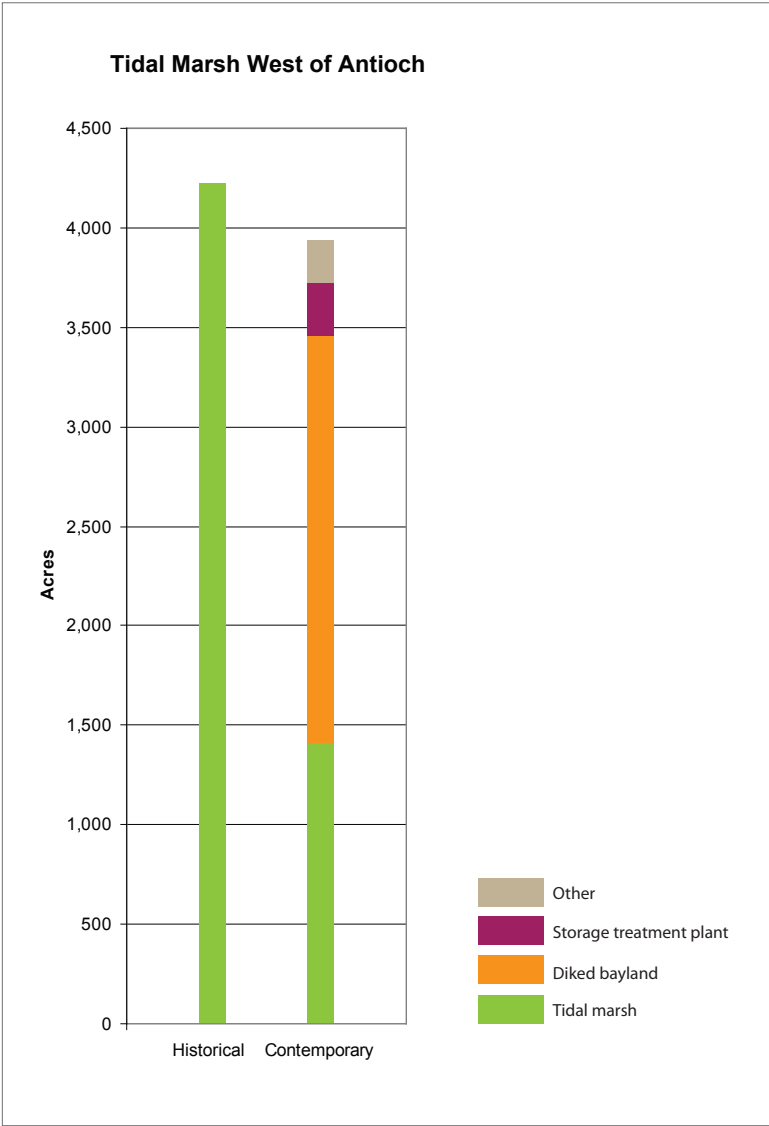


Figure 5.21. Comparison of historical and contemporary wetland habitats. These graphs compare historical and contemporary wetlands to show some of the changes since the mid-1800s. A) We focused on tidal marshes west of Antioch, as this was where we had the best data. The category “tidal marsh” includes 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

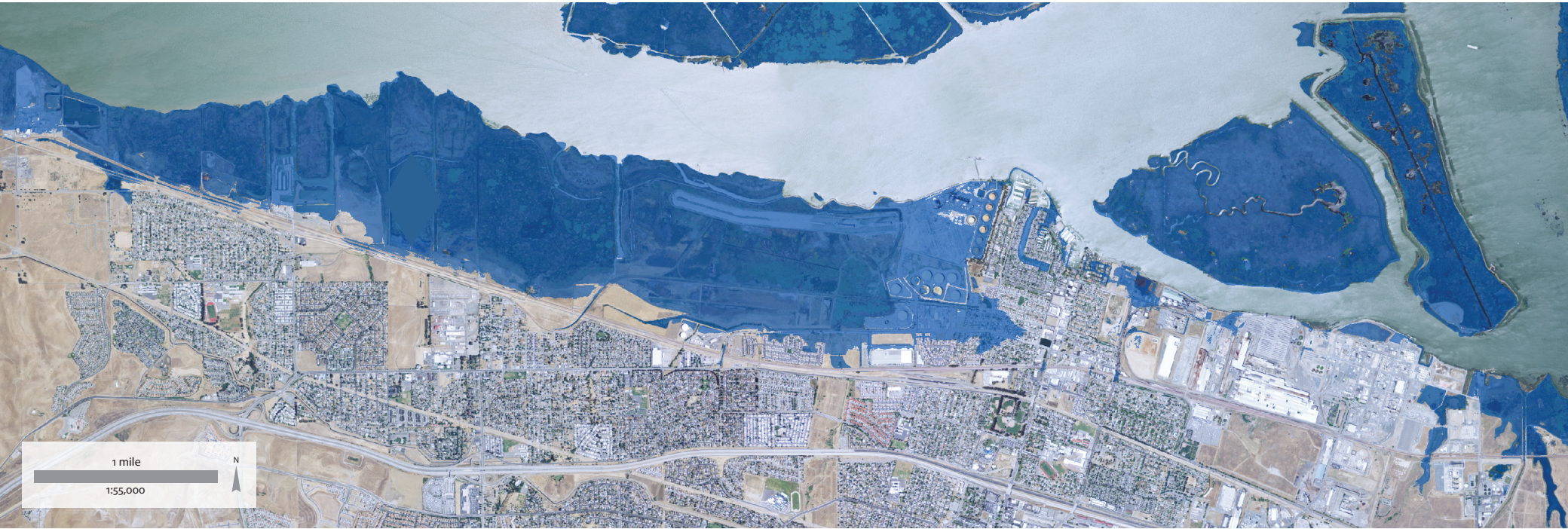


Figure 5.22. Tidal marsh and projected sea level rise. The contemporary aerial imagery is overlaid with the historical habitat map (top) and projected 1.5 m sea level rise at a one-year flood level (bottom). Rising sea levels would potentially cover much of the historical tidal marsh extent, drowning 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)

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 5.23. 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 across, alkali lands in the San Joaquin Valley and beyond through Southern

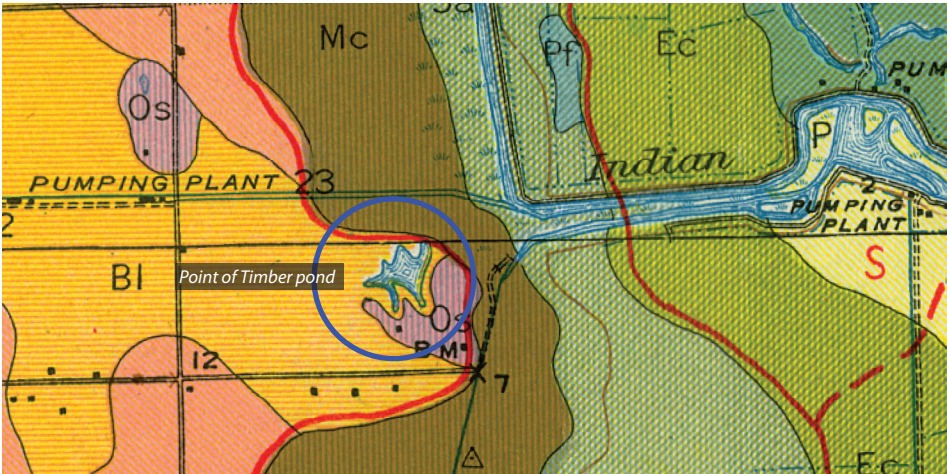
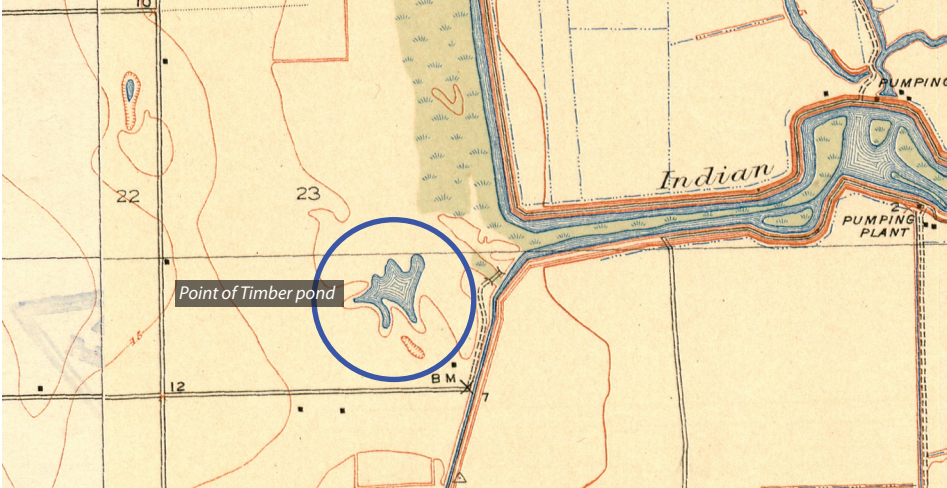
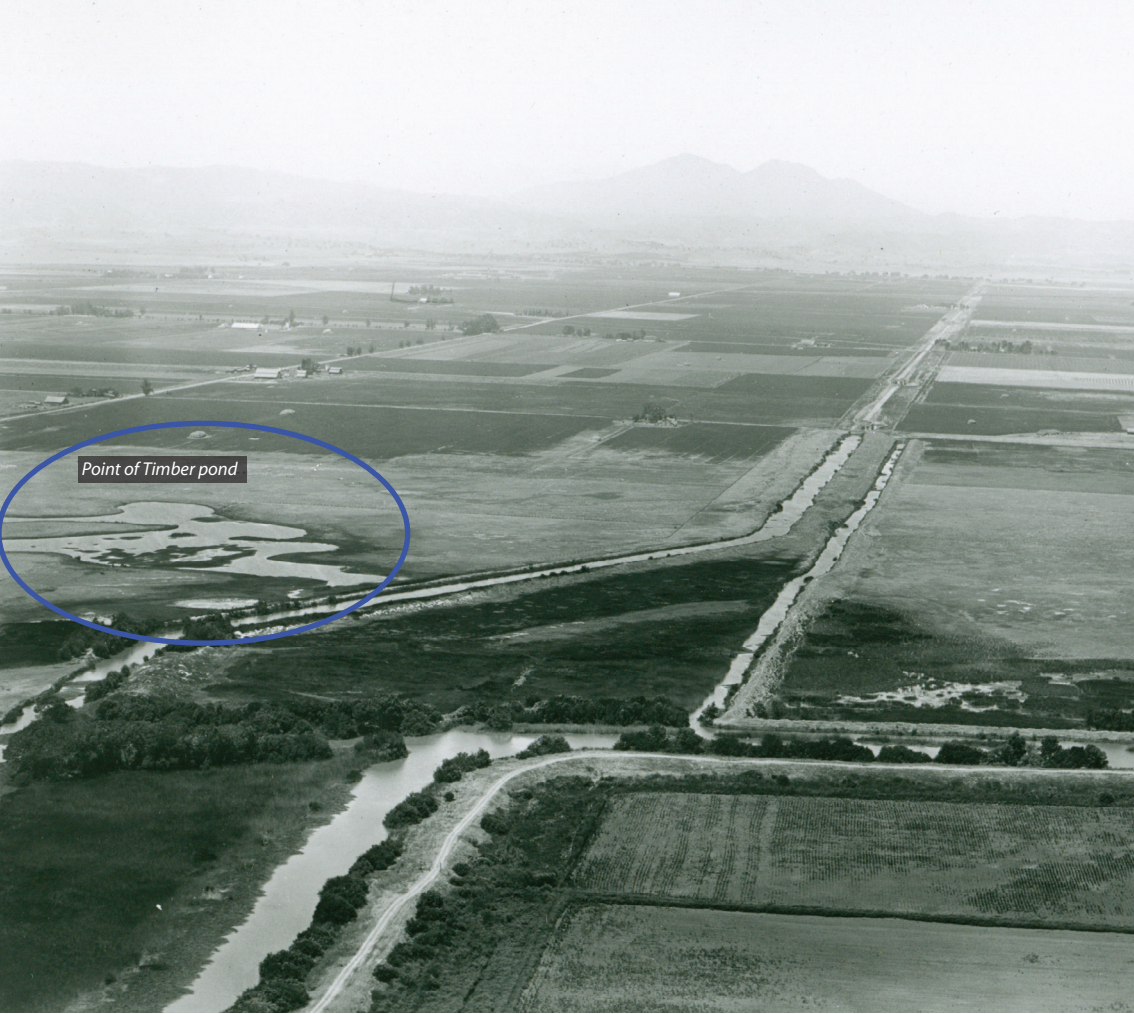


Figure 5.24. Historical representations of “Point of Timber” pond. These images consistently show the pond near the border of alkali habitats and tidal marshland. Note the patch of Oakley Sand (Os) on the soil survey southeast of the pond, which likely supported interior dune habitats. Note also the 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 brittscale. 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)



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. **Restoration 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 godfields (*Lasthenia* spp.), are visible around the edge of this vernal pool near the Byron airport. (Photo by Abigail Fateman, CCC)