4 STREAM AND RIPARIAN HABITATS

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

STREAM AND RIPARIAN HABITATS

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

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

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

METHODS

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

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

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

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

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

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

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

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

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

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

RESULTS

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

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

"Salmon weighing as much as 12 pounds have been recently caught in the streams near Gilroy. They evidently came up from saltwater."

– THE PACIFIC COAST, FEBRUARY 19, 1881

"The water outlets of Gilroy township... [afford] plenty of sport in the trout and salmon seasons..."

– MUNRO-FRASER 1881

Changes in the drainage network

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

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

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

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

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

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

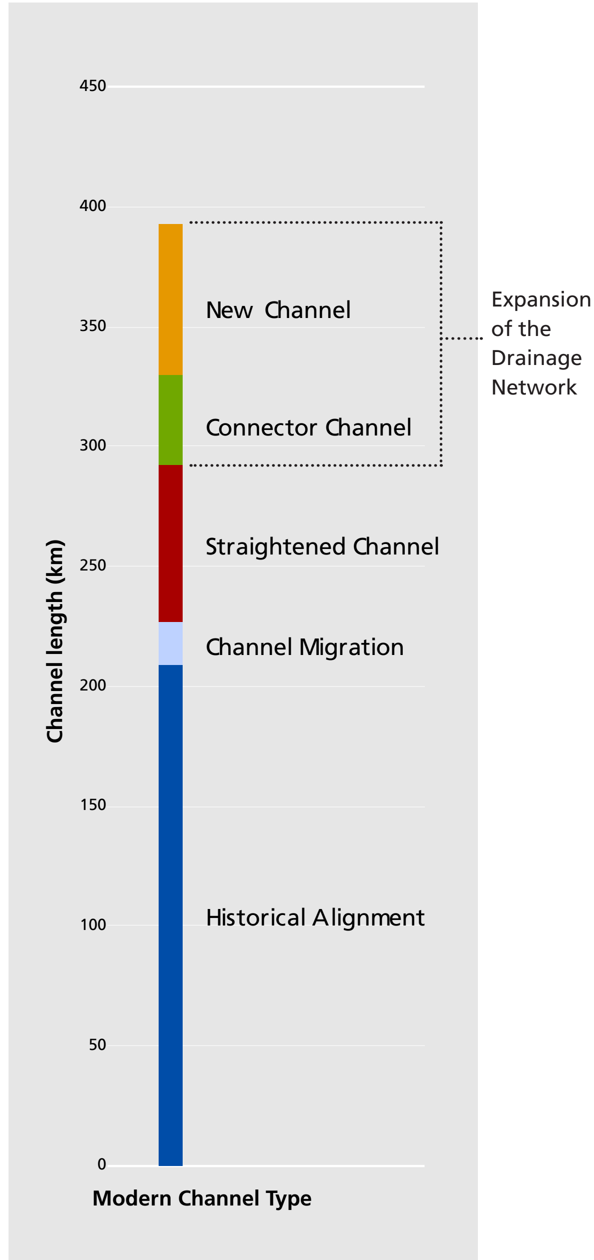


Figure 4.1. This figure describes the channels of the contemporary south Santa Clara Valley drainage network. It includes channels that follow their historical alignment and a small amount of channels that have naturally migrated. It also includes channels that have been straightened, channels dug to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

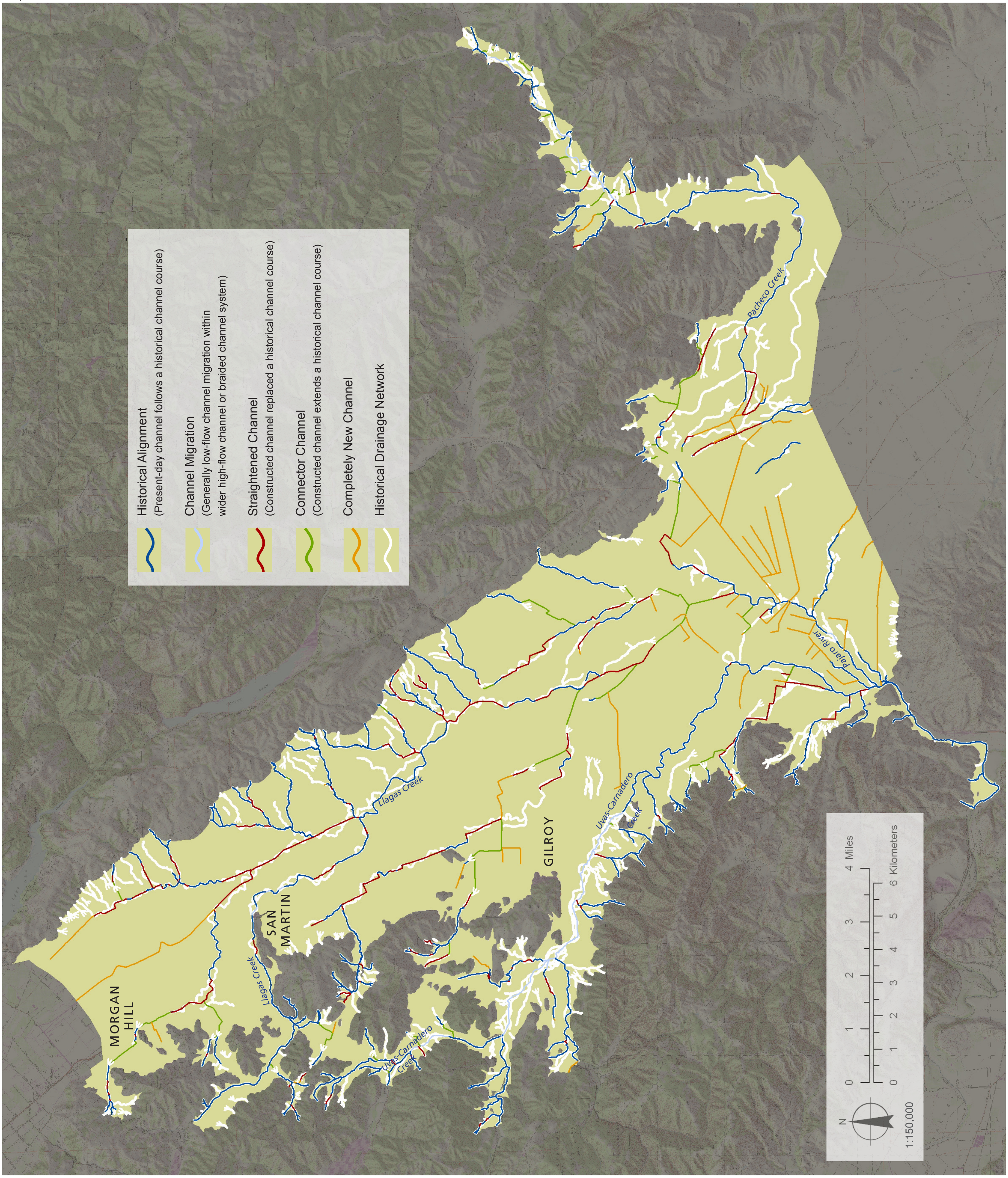


Figure 4.2. Map of the contemporary drainage network, with channels coded with regard to their origin. The historical drainage network is shown in white.

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

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

Discontinuous creeks and distributaries

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

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

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

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

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

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

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

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

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

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

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

Floodplain sloughs

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

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

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

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

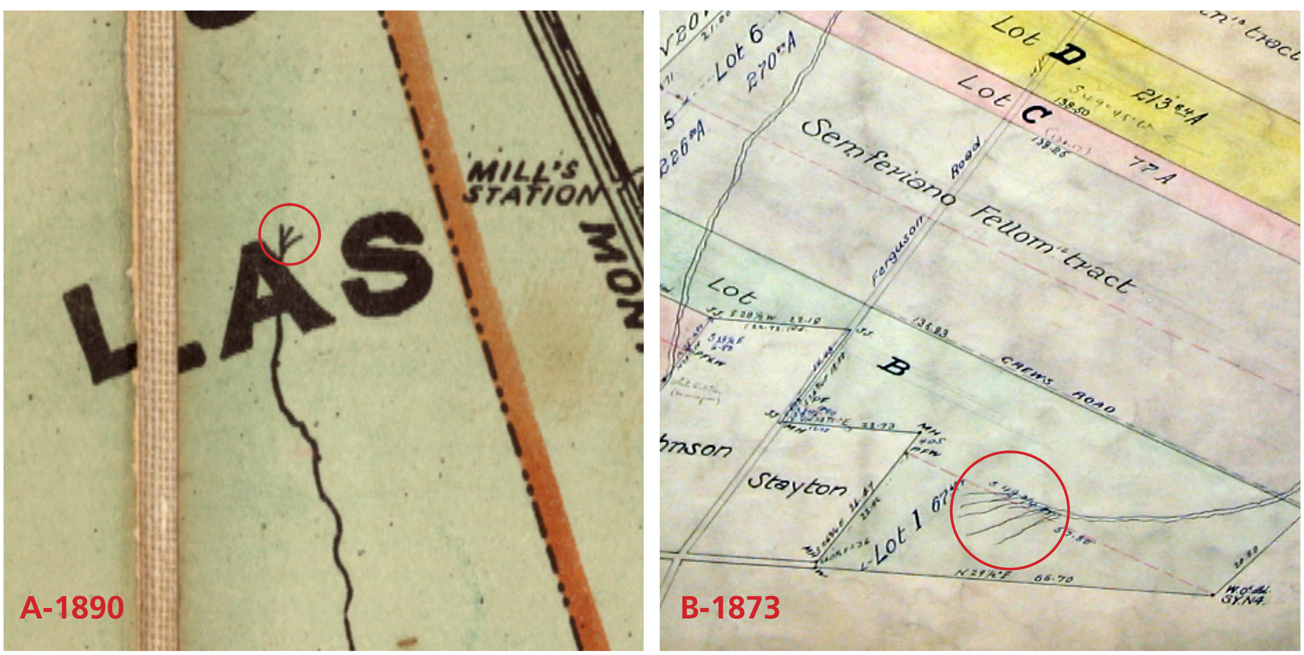


Figure 4.7. Historical maps commonly use the "crowfoot" symbol to show the point at which streams lose definition. (A: Herrmann Bros.1890, courtesy of Branner Earth Sciences Library and Map Collections, Stanford University; B: Herrmann ca. 1873b, courtesy of the Office of the Santa Clara County Surveyor)

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

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

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

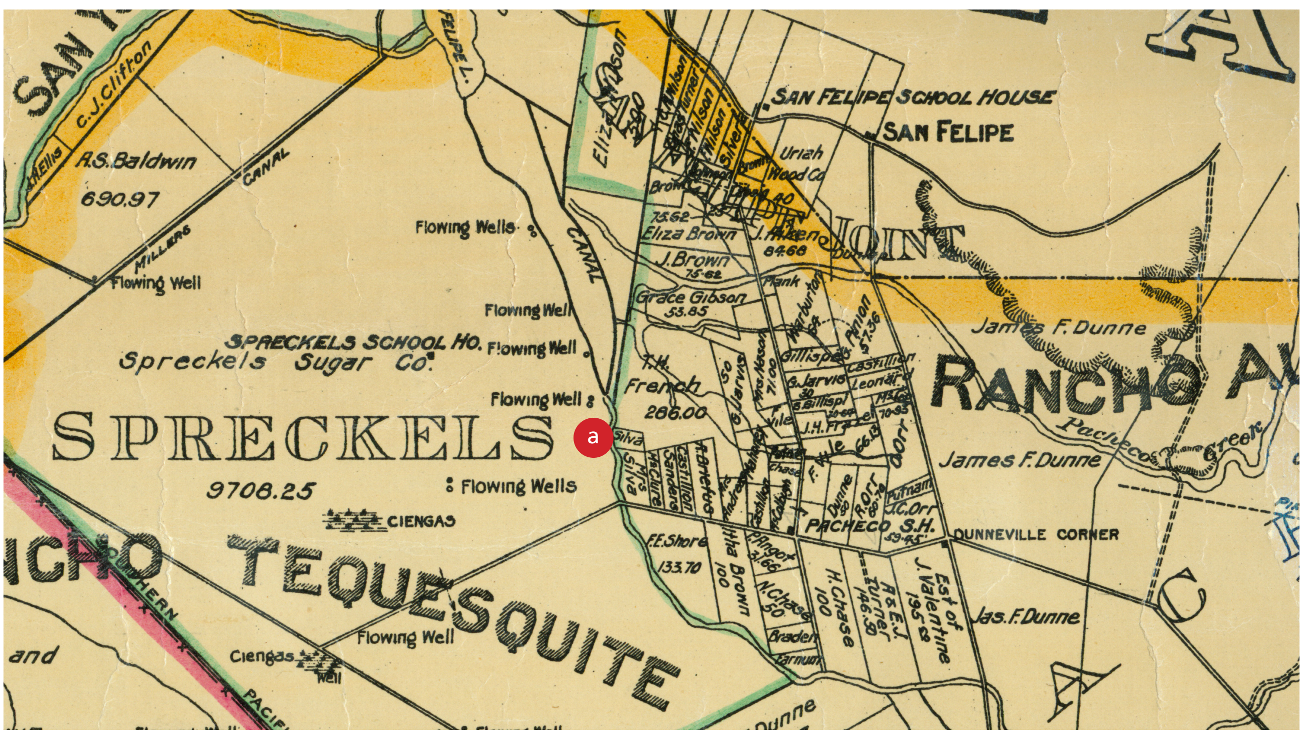


Figure 4.8. At the point where the grant boundary between ranchos Bolsa de San Felipe and Ausaymas y San Felipe leaves Tequisquita Slough, the slough is shown on this 1907 map as changing from a more well-defined channel (shown with double lines) to a less well-defined one (shown as a single line). A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

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

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

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

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

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

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

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

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

Riparian corridor width

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

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

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

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

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

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

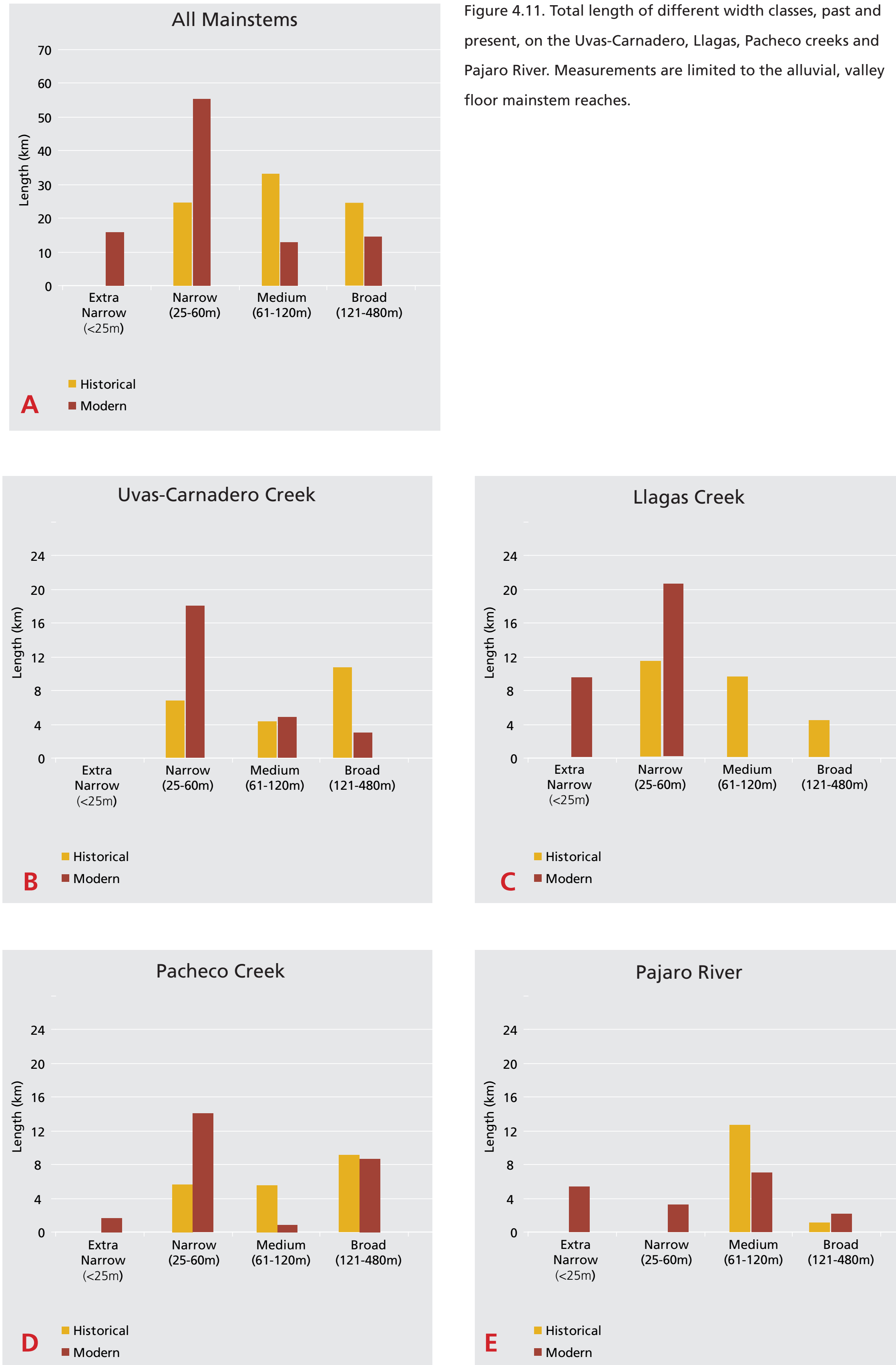


Figure 4.11. Total length of different width classes, past and present, on the Uvas-Carnadero, Llagas, Pacheco creeks and Pajaro River. Measurements are limited to the alluvial, valley floor mainstem reaches.

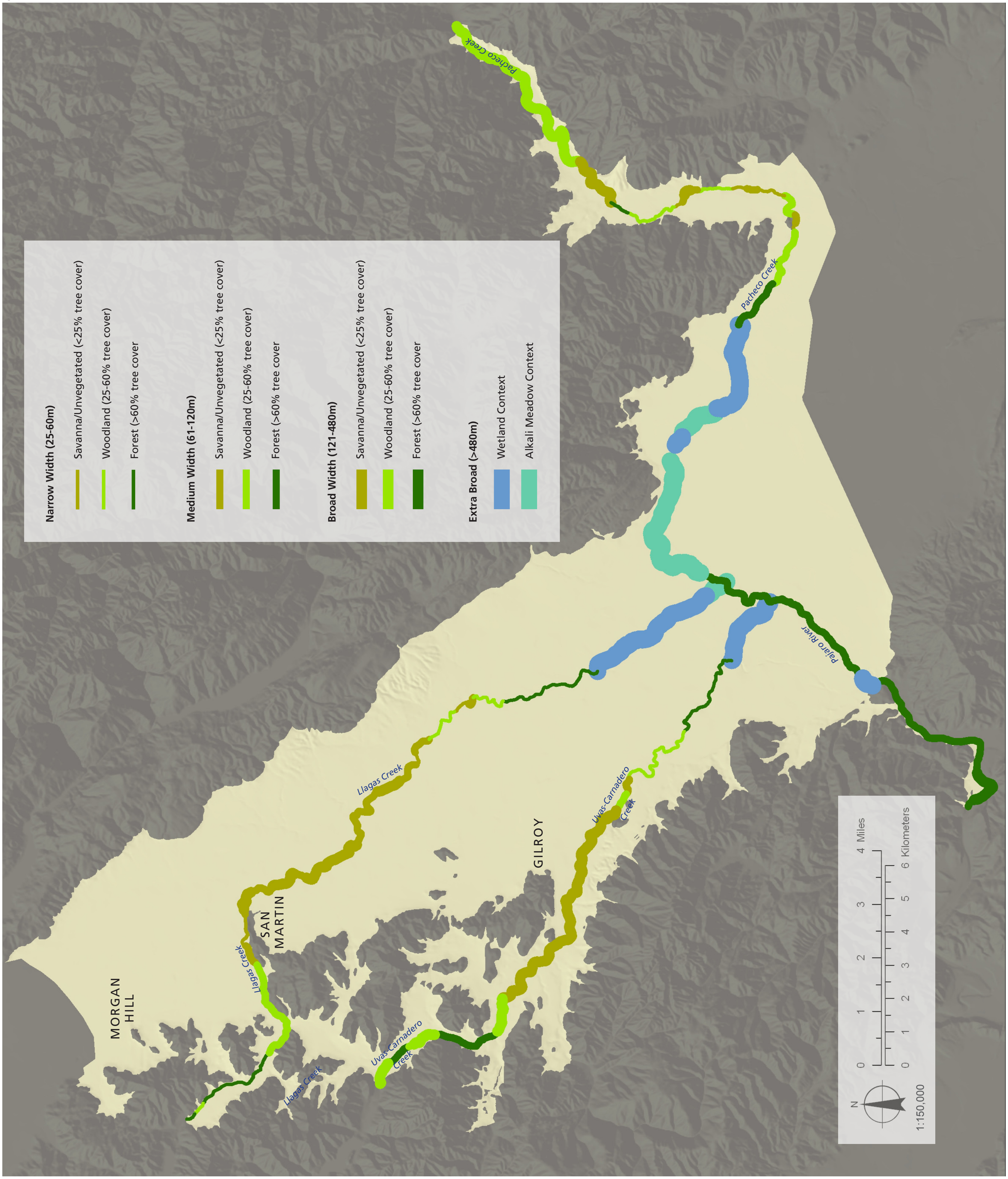


Figure 4.12. Historical riparian corridor width and architecture along major south Santa Clara Valley drainages. Width and riparian architecture/type classes are discussed in the text. Reaches without a single defined channel are described as either surrounded by wetlands or alkali meadows.

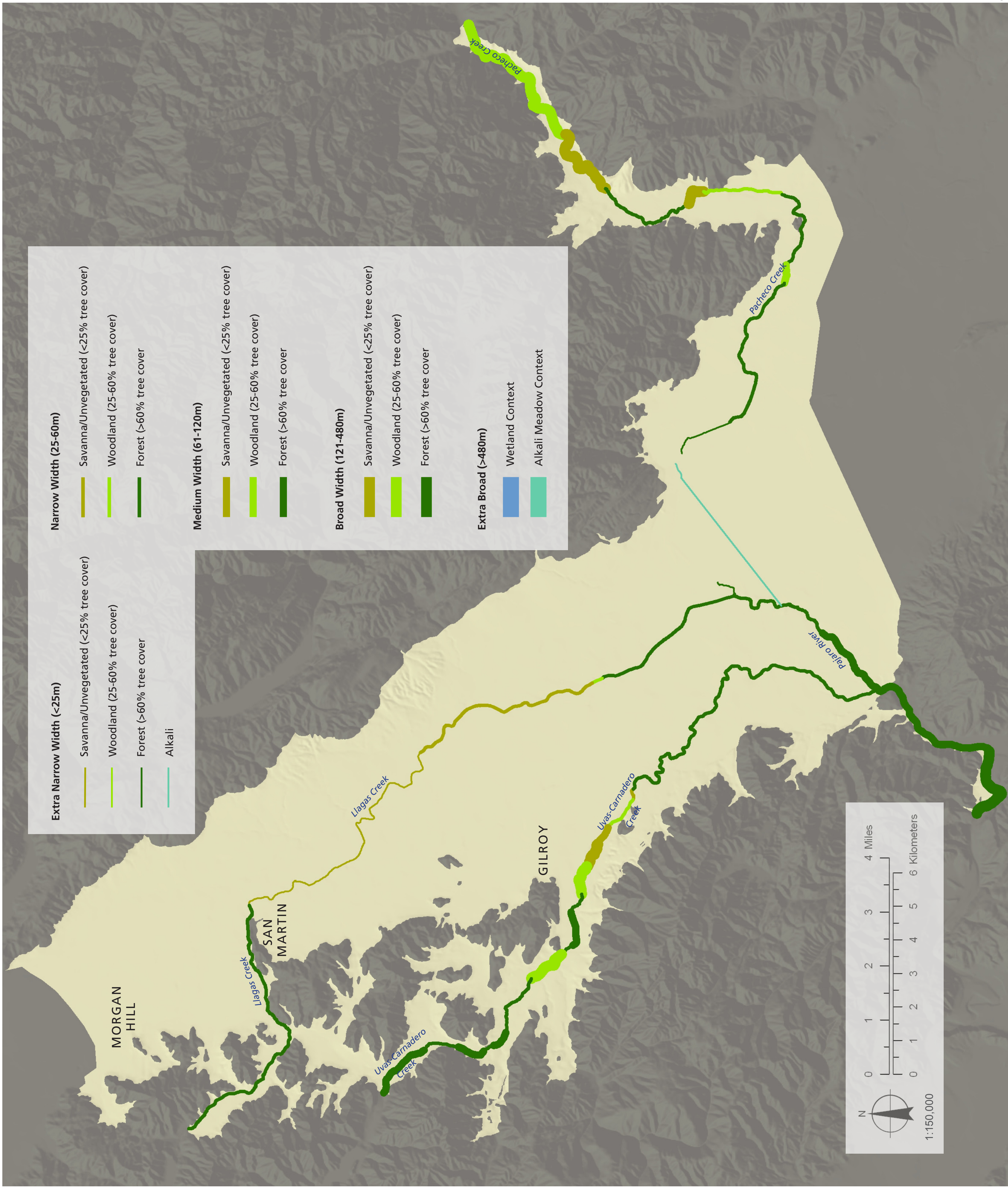
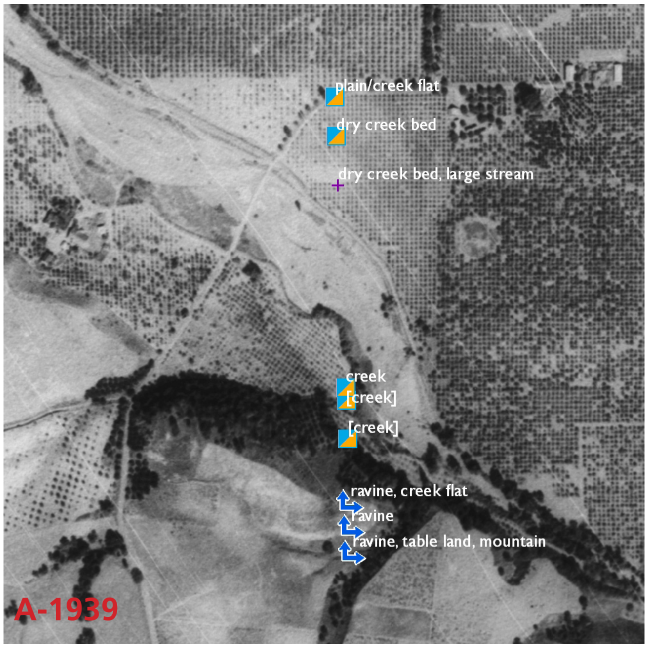


Figure 4.13. Contemporary riparian corridor width and architecture along major south Santa Clara Valley drainages. Width and riparian architecture/type classes are discussed in the text.



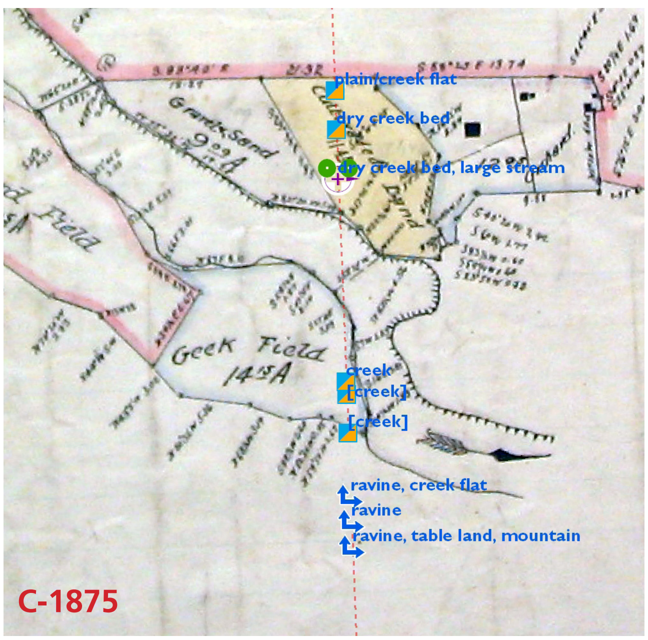


Figure 4.14. Historical reclamation of the Uvas-Carnadero Creek channel at Miller Avenue. This sequence of images compares information from four different eras. The base images are aerial photography from 1939 (A) and 2005 (B), and a county survey by Herrmann from 1875 (C). Overlaid on each of the images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

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

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

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

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

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

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

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

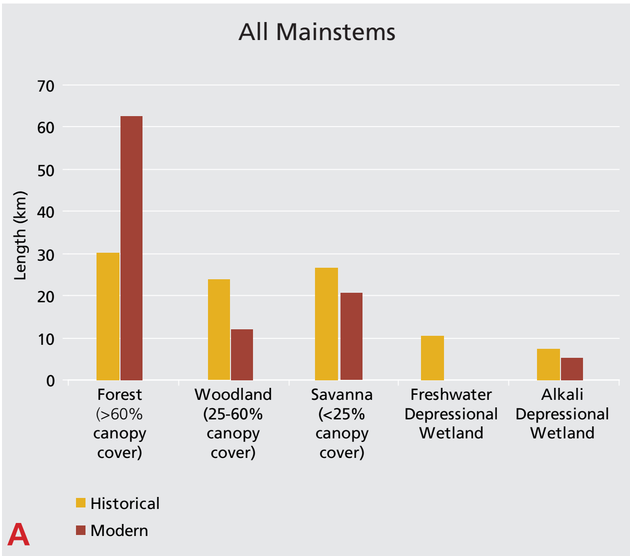
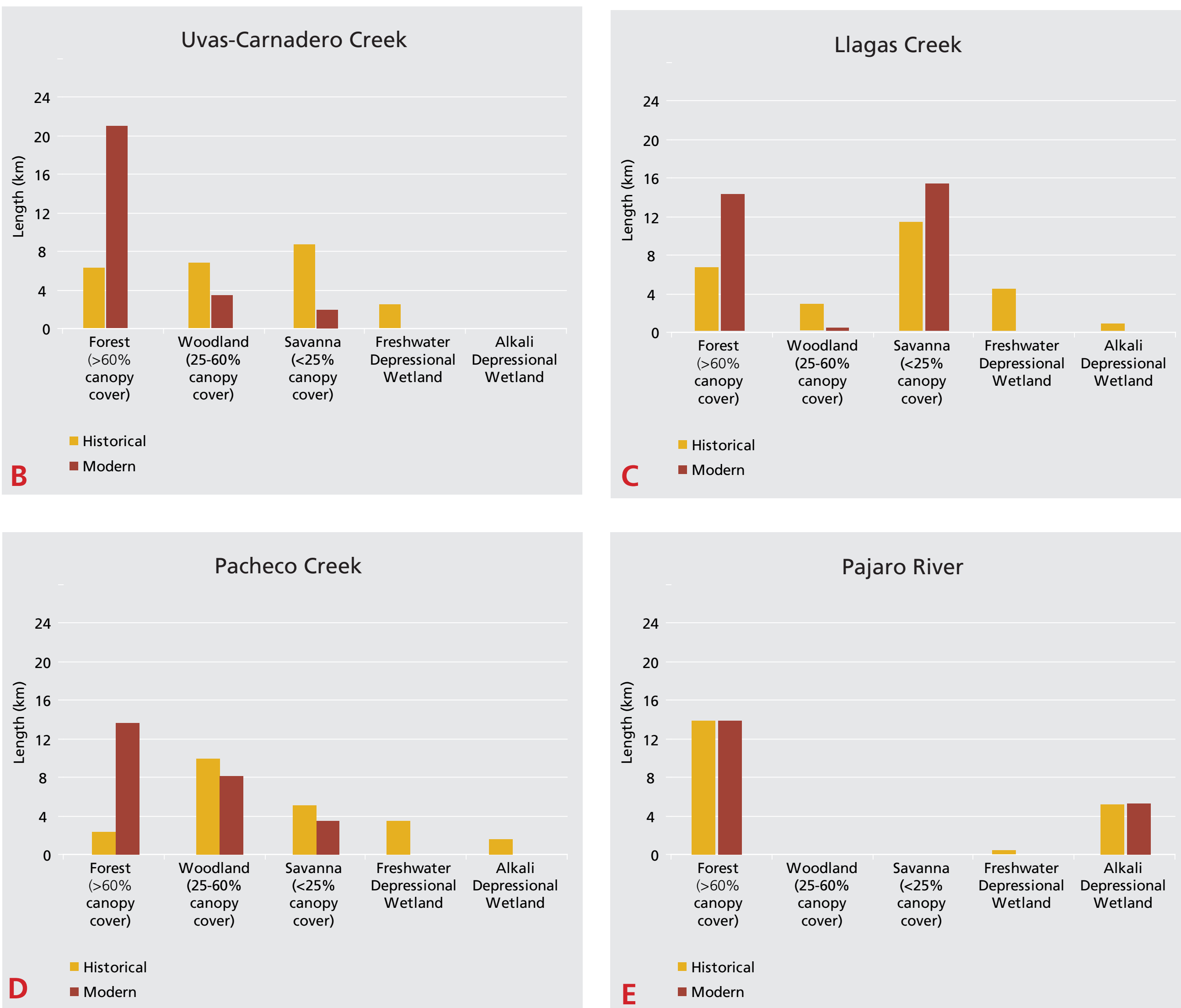


Figure 4.16. Total length of different riparian corridor types, past and present, on the Uvas-Carnadero, Llagas, Pacheco creeks and Pajaro River. Measurements are limited to the alluvial, valley floor mainstem reaches.



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

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

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

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

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

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

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

Riparian plant community composition

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

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

— BAYARD TAYLOR, IN LATE SUMMER 1850

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

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

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

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

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

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

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

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

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

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

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

"…a fair-sized river which runs through a heavy growth of cottonwoods, willows, and sycamores, with a good volume of water…"

— PALOU 1774, DESCRIBING THE PAJARO RIVER

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

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

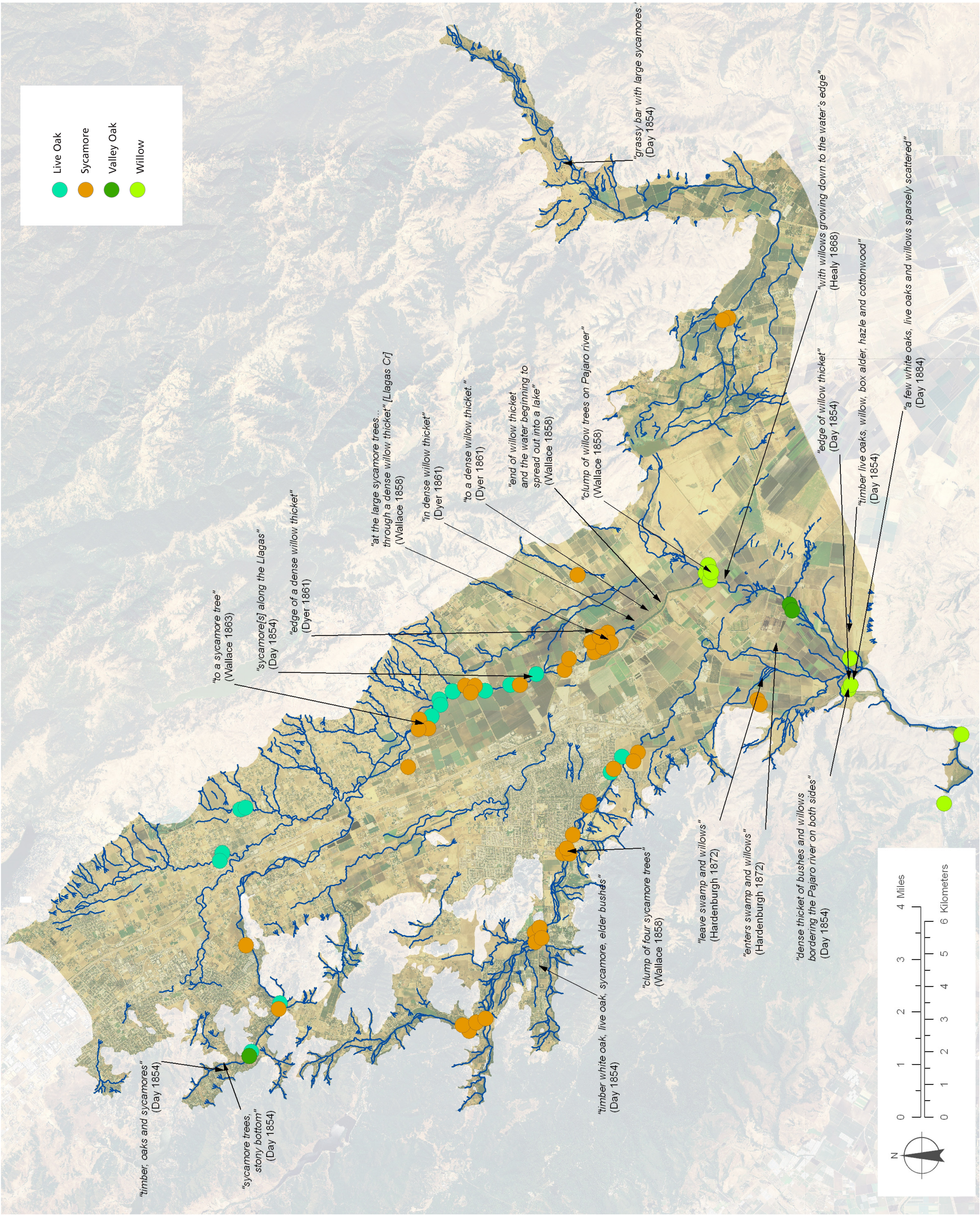

Live Oak
Sycamore
Valley Oak
Willow
"grassy bar with large sycamores" (Day 1854)
"with willows growing down to the water's edge" (Healy 1868)
"edge of willow thicket" (Day 1854)
"timber live oaks, willow, box alder, hazle and cottonwood" (Day 1854)
"a few white oaks, live oaks and willows sparsely scattered"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

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

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

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

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

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

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

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

Intermittent vs. perennial reaches

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

Figure 4.23. Historical evidence for dry season stream flow.

Table 4.1. Historical evidence for dry season stream flow.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Native Fish Assemblages

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

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

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

Perennial mainstem streams

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

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

Large discontinuous creeks and distributaries

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

Small discontinuous creeks and distributaries

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

Floodplain sloughs

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

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

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

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

Large tributary creeks (perennial mainstem)

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

Large tributary creeks (intermittent mainstem)

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

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

Small tributary creeks (perennial-to-intermittent headwater)

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

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

DISCUSSION

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

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

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

Expansion of the drainage network

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

Braided vs. single thread channel morphology

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

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

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

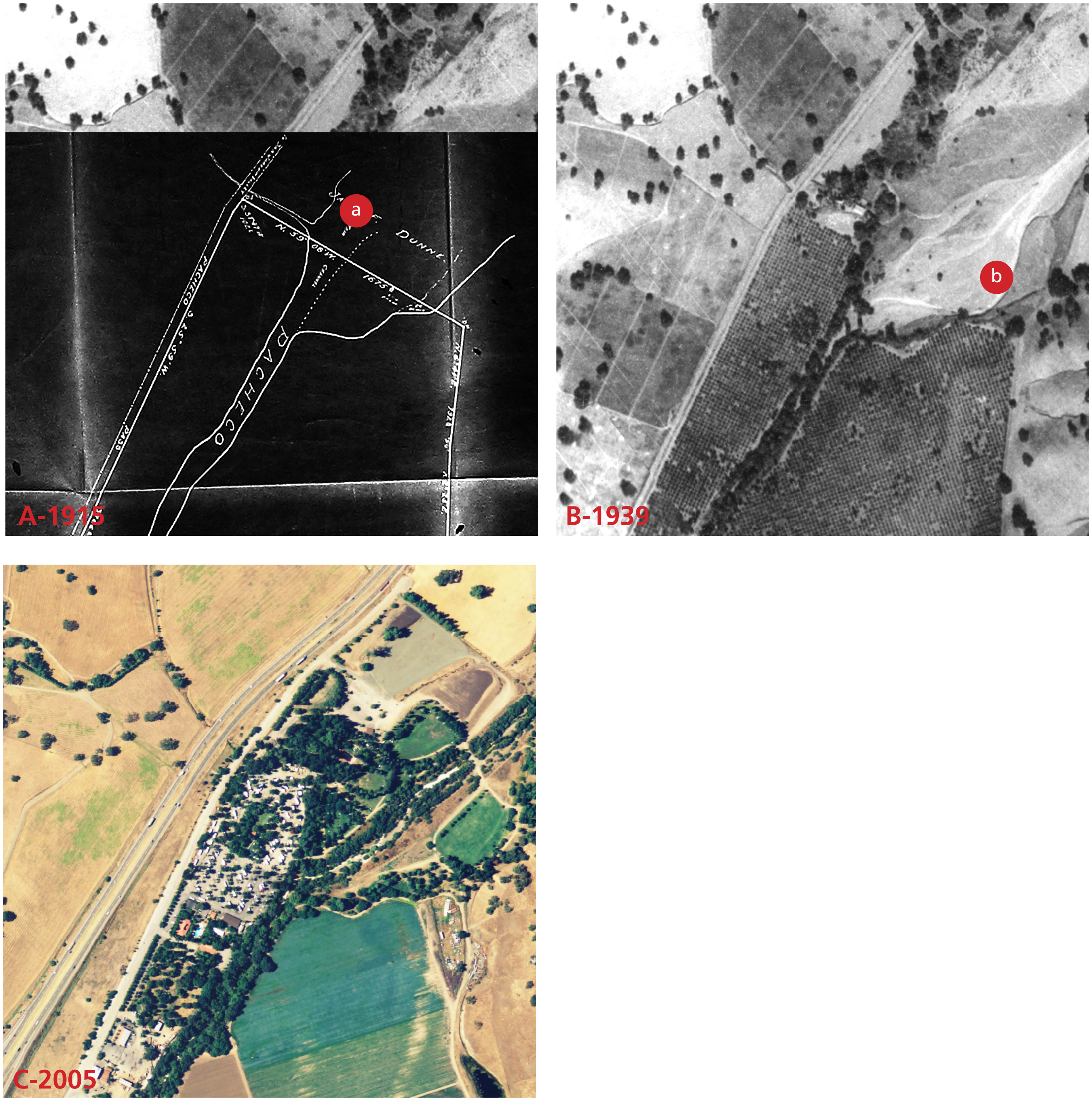


Figure 4.28. Transition from braided to single thread meandering channel on lower Pacheco Creek. The shift in morphology is shown in the exact same location by Winn (1915; A) as in 1939 aerial photography (B), although the main channel (a) moved from the west to the east (b). Most of the adjacent bars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

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

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

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

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

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

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

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

Sycamore alluvial woodland on Pacheco Creek

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

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

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

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

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

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

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

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

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

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

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

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

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

North Fork Pacheco Reservoir management

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

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

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

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

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

Sycamore restoration on other streams

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

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

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

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

Pulse flows

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

Intermittent stream values

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

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

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

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

Designing stream flows to support stream and riparian choices

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

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

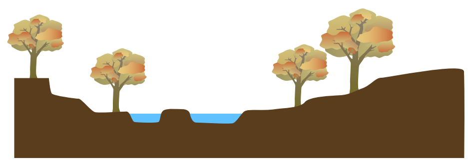
Given the challenge of supporting these various and sometimes competing natural resource objectives in the future, probable long-term system trajectories and design options should be considered by a multidisciplinary group with expertise in fish ecology, riparian ecology, fluvial geomorphology, and water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

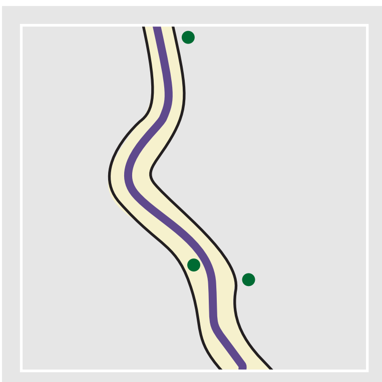
Landscape trajectories

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

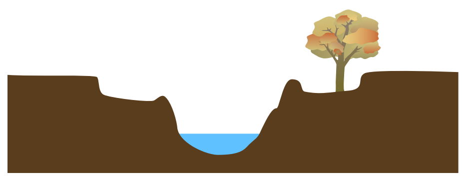
The effects of these large, post-World War II constructions are particularly wide ranging. However, the slower development of flood control efforts in the area means that significant projects, such as along the Llagas, are still underway, with the potential for incorporating riparian habitat and natural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

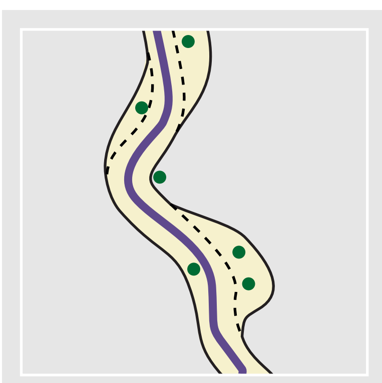
ca. 1800: Scattered California sycamores occupy banks, bars, and terraces along braided channels.





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





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

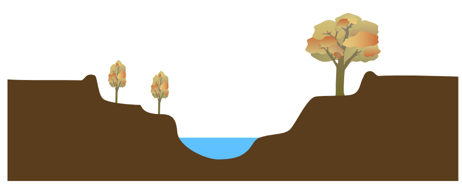


Figure 4.34. Braided stream channels with open sycamore canopy: conceptual model of landscape trajectory