

Final Draft for Review

**ECOLOGICAL, GEOMORPHIC, AND LAND USE HISTORY OF
THE SULPHUR CREEK WATERSHED:
A COMPONENT OF THE WATERSHED MANAGEMENT PLAN
FOR THE SULPHUR CREEK WATERSHED, NAPA COUNTY,
CALIFORNIA**



**PREPARED FOR
STEWARDSHIP SUPPORT AND WATERSHED ASSESSMENT IN THE NAPA
RIVER WATERSHED: A CALFED PROJECT**

**CALFED CONTRACT NO. 4600001703
NAPA COUNTY RESOURCE CONSERVATION DISTRICT**

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EXECUTIVE SUMMARY

During 2002-2003, the San Francisco Estuary Institute, with the assistance of the Napa County Resource Conservation District, carried out a study of the historical ecology of the Sulphur Creek Watershed. The resulting technical report is one of five produced to inform the development of a watershed management plan through a participatory process that includes the community, natural resource agencies, and scientists.

To assess historical land use and associated changes within the watershed, we used a multifaceted approach to collect and synthesize a diverse range of information. This process included collecting numerous historical documents from the 19th and early 20th centuries, analyzing historical maps and aerial photography, interviewing local residents, and assessing field conditions with other project team members. Interpretations were analyzed in the context of the findings of the other technical teams through project team meetings.

The Sulphur Creek watershed is characterized by a number of specific and locally uncommon landscape features that together have shaped the ways of life of the peoples who have settled in the watershed. This combination – including redwood forests, unstable hillsides, warm water springs, a braided channel, a broad alluvial fan, a stream running through an unusually large valley oak grove -- led to early logging, the development of a resort by the early 1850s, and the lower watershed's continued position as a center for American settlement in the upper Napa Valley.

The land use history of Sulphur Creek watershed differs from other watersheds in Napa Valley because of these locally distinct influences on cultural activity. Management activities have had a range of impacts, some of them quite complex. Some long-term activities, such as gravel removal and controlled burns, have tended actually to maintain historical conditions, probably reducing the extent of physical or ecological change that would have taken place otherwise. Other activities, such as the redirection of streams and the expansion of agriculture, have caused more dramatic, immediate changes.

Despite intensive land use during recent centuries, the Sulphur Creek watershed maintains a remarkable array of ecological resources that are valued by the community and likely to benefit from future stewardship. Understanding the sequence of natural and anthropogenic changes that have shaped the watershed to-date is an important part of establishing future directions for environmental management of this unique watershed.

This Historical Ecology report presents a number of specific implications for future management of the watershed; these are listed below. The report also provides a detailed summary of land use history and historical information resources, which are

intended to provide a basis for answering subsequent questions about the watershed history.

1. The broad, braided channel reach of Sulphur Creek is a natural phenomenon that is a unique feature in the Napa Valley. This persistent channel pattern has been created by relatively high sediment production rates in the watershed associated with the inherently erosive Franciscan Formation. The braided channel reach of Sulphur Creek contributes substantially to the diversity of stream habitat within the Napa Valley.
2. Sediment produced by the watershed has effectively balanced long-term gravel mining, which has been a significant activity since the latter 19th century. Observations since the termination of gravel mining indicate continued substantial deposition, with aggradation of as much as five feet in the past three years. It is expected that the stream bed will continue to aggrade without the removal of sediment from the braided section. This could lead to increased flooding and the risk that Sulphur Creek could reinitiate fan-building, reoccupying other parts of its alluvial fan.
3. With the cessation of gravel mining, additional sediment may be transported to the confluence with Napa River, particularly if engineering adjustments are made to reduce sediment deposition in the braided reach. The potential for backwater deposition in lower Sulphur Creek should be considered, particularly in relation to proposed flood control efforts.
4. Landslides are dated back to at least 1869, in the case of Devil's Slide. Landslides are a natural process within the watershed, but may also be triggered or exacerbated by land use activities. Clearing has been common in the watershed during historical times, but has increased substantially with the extension of vineyards into the upper watershed in recent decades. The extension of agriculture, and associated changes in drainage patterns, has the potential to trigger additional sediment production and watershed managers should be careful to avoid triggering new slope failures.
5. The density of woody vegetation in the upper watershed has increased substantially during the past 60 years, likely as a result of decreased fire frequency. This has probably increased the risk of significant fire in the watershed. A number of other valuable attributes of the watershed may also be affected by this change, with possible effects including reduced wildlife habitat, less accessibility to people, and decreased base flow in the stream. Controlled burns may be considered to address some of these concerns.

6. The braided channel section of Sulphur Creek has been both narrowed and shortened over the past 60 years, decreasing a significant area of sediment deposition/storage and reducing associated aquatic and riparian habitat.
7. The creation of a single thread channel in the presently braided reach would actually make the channel less similar to its historical, or "natural" character. Such a constructed channel may have difficulty moving the substantial sediment loads through this section and has some potential risk of failure.
8. The creek's riparian corridor on the valley floor is heterogeneous due to a diverse history of channel changes. Several distinct reaches were identified, with specific associated concerns:
 - a. Downstream of Main Street and upstream of the Pope Street Bridge, efforts should be made to enhance the limited riparian overstory;
 - b. On the lower creek upstream of the flood control channel, an older section of mature riparian canopy was identified. Many of the trees in this section, which provide shading for fish passage and aesthetic value to the neighborhood, are substantially undercut. Further incision could cause a high rate of fall into the creek;
 - c. A section of new riparian canopy that has developed on a reach of the stream constructed less than 60 years ago suggests the potential success of riparian habitat restoration with adequate protection from adjacent impacts.
9. Qualitative observations of both incision and aggradation in the lower reaches suggest that the creek is actively responding to recent changes in its management, such as the termination of gravel mining and, perhaps, the original creation of the existing flood control channel. Further study is appropriate to assess these responses and the potential responses to current and future projects. A continuous stream survey of bed elevation and bank erosion may be useful to assess the preliminary observations of streambed change. Projects proposed in the braided channel and flood control reaches should be considered with regard to their effects on incision/aggradation in the reaches upstream and downstream.
10. The historical valley oak savanna that characterized the lower watershed still exists as remnant trees within the town of St. Helena. This element of the community's heritage could be enhanced and maintained for future generations by restoration activities.

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We would like in particular to acknowledge the watershed residents who generously contributed their time and expertise about the history of the land and the people, flora, and fauna that it has supported over the last several hundred years: David Garden, Babe Learned, Sandra Learned Perry, Jim Perry, Tom Wilson, and Harold and Jack Varozza. The impressive knowledge of local residents is one of the valuable resources of the Sulphur Creek watershed.

This focused study of the landscape history of one subwatershed of the Napa River basin was made possible by the work of the basin-wide Napa River Watershed Historical Ecology Project (NRWHEP). The NRWHEP, established in 1999 by San Francisco Estuary Institute and the Friends of the Napa River (FONR), provided a foundation of historical resources and analysis, which was built upon and expanded in this project. Special thanks are due to Chris Malan and Shari Gardner of FONR for their tireless efforts to develop these valuable resources for understanding the ecological history of the region, and the NRWHEP sponsors: the Mead Foundation, the Mennen Environmental Foundation, and the Napa Valley Vintners Association.

We would like to thank Mike Champion of the Napa County Resource Conservation District for his research efforts on behalf of the project, particularly through interviews with local residents and archival newspaper research. Numerous other individuals have provided valuable knowledge and insights to the research presented here, including Jake Ruygt, Phill Blake, David Graves, Ellie Insley, Michael Napolitano, Stephen Rae, Parry Mead, Laurel Collins, Arthur Dawson, and Garrett Buckland.

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The analysis of 1940s aerial photography was made possible by Phill Blake of the Natural Resources Conservation Service, who provided the imagery, and Thomas Burns of GIS Mapping and Analysis (agismap1@maine.rr.com), who created the georectified photomosaic. Jeff Kennedy, Mike McCoy, and Jim Thorne of the Information Center for the Environment at UC Davis generously facilitated our use of the new Napa Vegetation Map developed by UCD, CNPS, the Land Trust of Napa County, and others.

Special thanks are also due to the many individuals who have maintained these valuable resources over the years, and helped us find them at the local archives, including The Bancroft Library, the UC Berkeley Earth Sciences and Map Library, the Napa Historical Society, the UCB Water Resources Archive, and the CA State Library.

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INTRODUCTION

The watershed of Sulphur Creek flows west to east entering the mainstem of the Napa River in the town of St. Helena (Figure 1). The watershed sustains a number of land uses including viticulture, rangeland, open space, rural residential, and, in its lower reaches, fairly dense urban settlement. The upper watershed is dominated by rolling hills with occasional steep ravines and escarpments and is generally well vegetated on hillslopes and in riparian areas, as a result of moderate rainfall and perennial stream reaches. The watershed supports a native steelhead population that may be negatively affected by reductions in summer flow, barriers associated with bridges and grade controls, and increases in fine sediment supply due to land management. All of these factors, with the addition of gentle fan topography in the lower watershed, provide the backdrop to a tranquil urban setting today and a history of resorts and warm-spring spas spanning nearly a century and a half.

In recognition of development pressures on the watershed, conflicting social and political interests, concern of unabated influences of regulatory agencies, and the potential decline in community value of the creek and watershed, a group of concerned stakeholders formed the Sulphur Creek Stewardship. The mission of the Stewardship is to preserve and maintain Sulphur Creek watershed in a natural and beautiful state and to promote both agricultural as well as private recreational usage. There have been a number of successes so far, including stream setbacks, erosion control of unstable banks, placement of a fish ladder, and plans to improve bridge crossings. Current concerns include fine sediment supply from hillsides, the effects of cessation of gravel mining in the fan reach just upstream from the town, and the design of a restored channel after the removal of a grade control in the fan reach.

Quality, defensible science is an important precursor to sound environmental management and restoration decisions. Once the community has constructed a set of management questions or desired uses for their watershed, sound science protocol is applied within a framework of continued community involvement to develop appropriate watershed management plans. The assumption is often made that a single science methodology can be used to answer all of a groups management questions, however, the best way to apply environmental science methodologies is to use a variety of protocols that have overlap in the scope of information that they provide. In this way, any conflicting conclusions that are derived from each isolated protocol are reconciled during the planning process, increasing the chance of restoration success.

In order to develop an understanding of the physical, biological and human aspects of the Sulphur Creek watershed at a variety of scales, we carried out the following types of empirical data collection and/or review of existing information:

1. Historical ecology
2. Channel geomorphology,
3. Hillslope geomorphology/ sediment budget,
4. Fish habitat assessment,
5. Water quality.

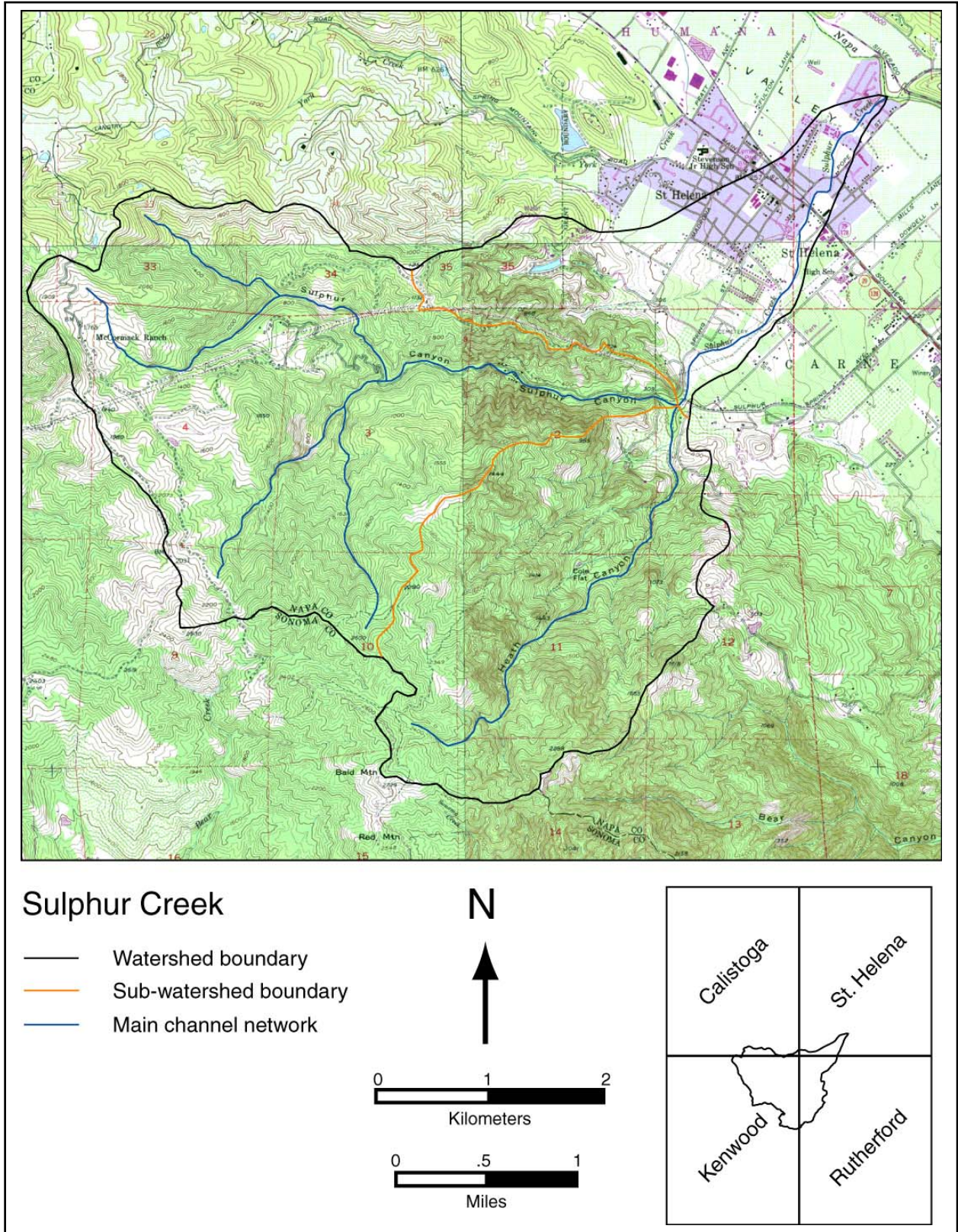


Figure 1. Map of the Sulphur Creek watershed.

This technical report describes the methods, results and conclusions derived from the Historical Ecology component and is part of the larger study outlined above. (The other project technical reports are referenced in this report by the above names.) This report will be integrated with other technical reports by the project partners in close consultation with the Sulphur Creek Stewardship, to create a management plan for the local community.

METHODS

We used a multifaceted approach to build a strong historical dataset and analyze key questions about historical land use and landscape change in the Sulphur Creek watershed. Key components to this approach, described in Grossinger (2001), include the following.

Use of different types of historical data. Since each historical data source provides only a selective view of environmental conditions, overlapping materials of different scale and purpose are required to create a relatively unbiased picture (Collins et al. 2002). Historical geomorphic or ecological assessments are commonly limited to either 1940s era aerial photography, standard local histories, or historical USGS quadrangles, producing findings which are largely shaped by the choice of data source. This study provides a more realistic picture of baseline watershed condition by incorporating information from many other sources, including official survey data of the General Land Office and U.S. Surveyor General, Mexican land Grant materials, extensive historical maps and texts, and land use history interviews with local residents.

Assessment of pre-European impacts. There is a tendency to overlook the role of Spanish/Mexican and Native land uses in shaping the present-day environment, probably because this analysis requires the use of a different suite of historical documents and associated analysis. The research performed here incorporates a reconstruction of Mexican land use practices and timing, and uses archeological and ethnographic information to assess the effects of the periods prior to American settlement.

Historical documents are tested for accuracy, rather than assumed to be correct. Key interpretations of a given historical map feature, for example, are based upon intercalibration with contemporary sources, understanding of landscape processes, and knowledge of the technical strengths and limitations of the map type, its author, and intended use.

Determination of the actual land use history of the watershed, rather than assumption of generalized regional land use patterns. This element turns out to be particularly important for this project since not only is the sequence and timing of land uses in Napa Valley substantially different from most of the Bay Area, but also Sulphur's history differs significantly from that of other sub-watersheds of the Napa River watershed, such as Carneros Creek (see *Carneros Creek Historical Ecology* report. To minimize the problem of basing interpretation of trends or change on just one historical data point, information from different decades was developed along with a supporting history of human settlement and cultural change.

One of the goals of the Historical Ecology component was to develop an information base of that would provide a useful foundation for subsequent projects by the Sulphur Creek Stewardship group. As stewardship efforts are considered and implemented over the coming years, a diverse range of further questions about historical changes to the watershed will most likely arise. As a result, we attempt in this report to both analyze key current concerns and provide a baseline historical perspective on the native, Spanish, and American history, and associated landscape changes, to inform future discussions.

Historical Data Collection

Archival research was carried out at numerous institutions. Some of the most important areas of archival research were the records of the Mexican Land Grant Cases and other historical accounts, at Bancroft Library; historical texts, newspaper archives, and early photographs, at the Napa Historical Society and Sharpsteen Museum; archeological and ethnographic records, from the Northwest Information Center at Sonoma State University; General Land Office Township and Range data, from the BLM in Sacramento; United States Coast Survey maps, from the California State Lands Commission, the National Ocean Survey (Rockville, MD), and National Archives II (College Park, MD). Several other archives provided fewer, but important, sources. We also acquired a number of useful historical texts from used bookstores with relatively small expense and delay through *abebooks.com* and *amazon.com*.

It was possible to acquire the quantity of historical data required for this analysis because of the extensive historical archive developed by the ongoing Napa River Watershed Historical Ecology Project. Assistance was also provided by Mike Champion of the Napa RCD and by Arthur Dawson of the Sonoma Valley Historical Ecology Project, a joint effort of Sonoma Ecology Center and SFEI.

Interviews

Because the Sulphur Creek watershed includes a number of longtime residents who have been actively involved in managing and observing the land as part of farming and ranching activities, interviews about 20th century land use and landscape changes were particularly important. Many of these were coordinated through presentations at the meetings of the Sulphur Creek Stewardship Group. Interactions were facilitated by Leigh Sharp and interviews were carried out by Elise Brewster and Mike Champion, as well as through discussions with residents in the field by Sarah Pearce of the geomorphology team.

Land Use Mapping 1940-1993

To provide a more detailed picture of land use changes within the watershed during the 20th century, we mapped general habitat types and land uses for the watershed using georectified, grayscale photomosaics. For a recent view, we used the 1993 Digital Orthophoto Quadrangles of the USGS (<http://wgsc.wr.usgs.gov/doq/>). We used the 1993 dataset because (1) it is the most recently georectified and mosaicked aerial imagery currently available for the region and (2) it is the base imagery being used by UC Davis Information Center for the Environment (ICE) for their development of present-day vegetation maps of Napa County, allowing coordination of mapping for change analysis (Thorne et al. [in press]). Draft coverages from ICE were used to develop the polygons for "Grasslands/Range" in Figure 6 (p. 27). For our purposes, floral alliances under the California State Vegetation Mapping Hierarchy used by ICE were merged

into larger, more general categories (i.e. Herbaceous alliances 6000-7200 were merged into our single category of "Grassland/Range").

For the earliest possible historical comparison, we created a digital photomosaic using 82 high-resolution photographs provided by Phill Blake of the NRCS. These images from 1940 and 1942 (and a single photograph from 1953) represent the earliest available set of direct overhead imagery for the Napa River watershed. Landscape change during this time period is presented through comparative maps and paired 1940/1993 photographic examples.

Mapping agricultural types circa 1940.

Mapping units were determined based upon (1) discussions with members of the other technical teams about which habitat or land use distinctions would have significant influence on the production of sediment and runoff, and (2) assessment of habitat/land use distinctions which were technically possible given available information. Some units were easily distinguished, such as the regularly-spaced, large "dot" pattern of *Deciduous Fruit, Nuts, and Olives* (Orchard) and the water surfaces of *Reservoir*. Vineyards were also relatively easy to determine because of their visible rows and the numerous examples available in the present-day imagery.

Greater uncertainty is associated with the distinction between the *Hay, Grain, and Miscellaneous Agriculture* and *Grassland/Range* units, which did not exhibit clear markers from above. To calibrate the imagery, we used other historical sources to identify crops at specific sites near the time of the earlier photographs. For instance, the site of the Spreckels Ranch south of the town of Napa provided the example of several hundred acres of hay and grain around 1940 (Weber 2001: 16, 281). Similarly, the UC/USDA map of "Farming Areas" circa 1930 (Crawford and Hurd 1935) shows general crop patterns that correspond with areas visible on the 1940 photography.

Where we could not distinguish grazing vs. general agriculture solely based upon photographic information, we utilized information about general land use of soil types. Some general assumptions were used in these cases to supplement visual information. For example, at this time fertile valley soils were rarely used for grazing and other soils were used almost exclusively for grazing (Carpenter and Cosby 1938). Uncertainty is greater in the case of these distinctions. The certainty of classification is recorded in the feature attribute tables of the GIS coverage. Horizontal accuracy of the circa 1940 coverage is limited by the challenges of historical photographic georectification. Horizontal error in this coverage can be as much as 50-80 m but is more typically <20 m.

Historical Rainfall Record

Cultural land management activities and watershed conditions evolve in the context of changing climatic conditions. To assess climatic variability during the historical period, we used a recent analysis of historical annual rainfall records for the North Bay and San Francisco by McKee and Grossinger (unpublished manuscript). This analysis uses correlation to early San Francisco rainfall records developed by Jan Null (pers. comm.; <http://ggweather.com>) to extend North Bay data back to 1850 (Figures 2 and 3). Data for St. Helena was obtained from the St. Helena Star (1989), provided by David Garden.

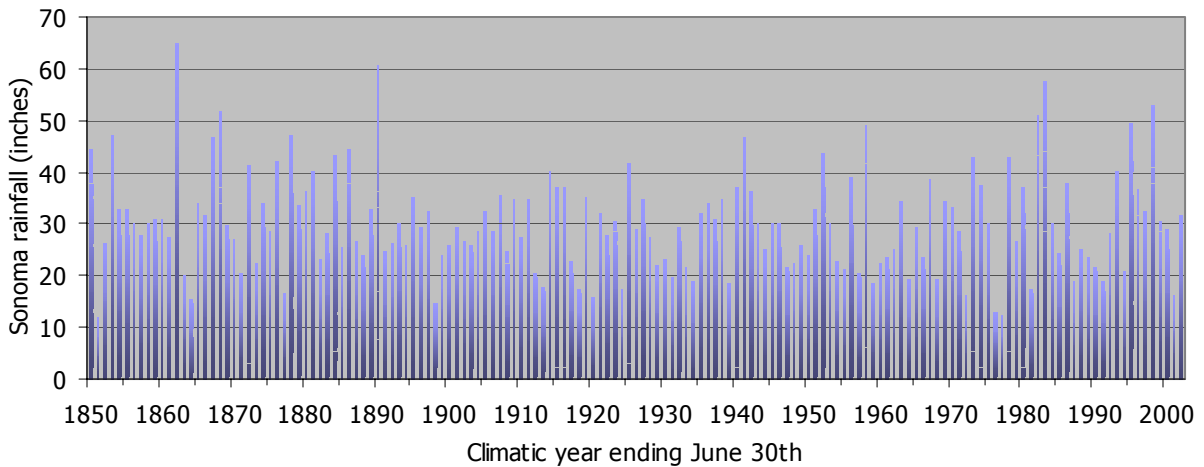


Figure 2. Annual rainfall at St. Helena for the period water year 1850 to water year 2002. Data are from local measurements subsequent to 1908, with earlier values calculated from San Francisco data ($r^2=0.82$).

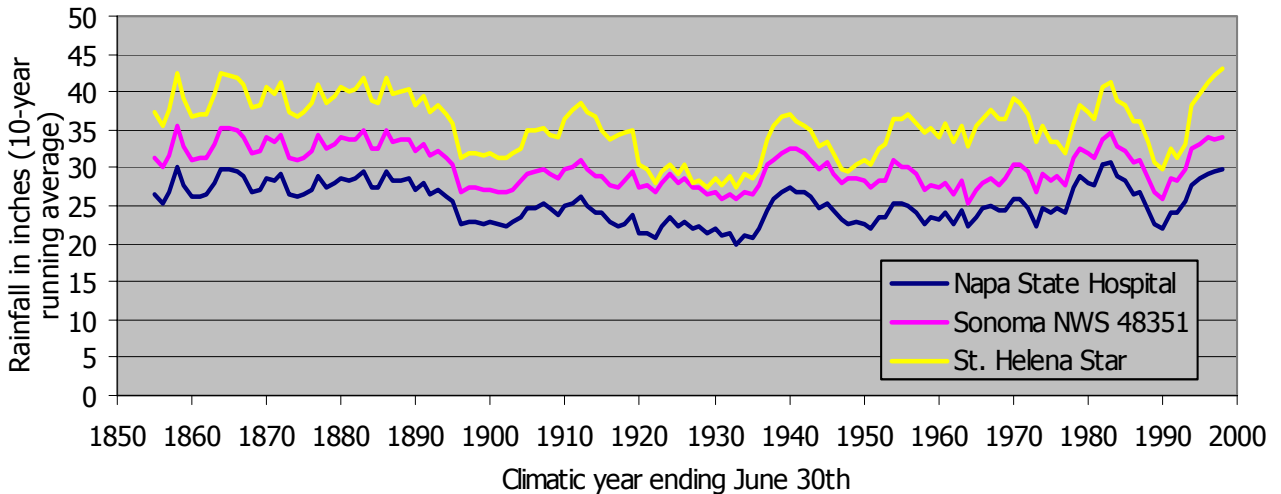


Figure 3. Ten-year running average annual rainfall at St. Helena compared to Napa and Sonoma for the period WY 1850 to WY 2002.

RESULTS AND DISCUSSION

The following three sections describe the findings of the Historical Ecology component of the Sulphur Creek Watershed Assessment. First, transformations in human settlement since European contact are described in **Cultural Context**. The **Land Use** section then details the types, duration and intensity, and potential effects of different land uses practiced by people within the watershed over that time. Actual physical changes in watershed resources and processes during historical times, as evidenced by historical and modern data, are described in the third section, **Landscape Changes**.

I: CULTURAL CONTEXT

An important step in developing a landscape and land management history for Sulphur Creek is to understand the origins and numbers of people that inhabited the land and how human populations changed through time. Newcomers to the Napa Valley often brought with them tools, experience, and land management practices from other places that with time were adapted to deal with local conditions. Understanding these dynamics is a critical component to documenting and understanding changes in the landscape.

Indigenous peoples

At the time of European contact, the Napa Valley comprised a complex mosaic of different linguistic and cultural groups, including peoples who had inhabited the Bay Area for at least 4,000 years (Calkins 1994). At least three distinct languages were spoken along the Napa River. The people of the upper Napa Valley spoke Wappo, an isolated and likely very old language whose range extended northward to approximately the Russian River. The Patwin language was spoken below the present-day town of Napa, and east into the Suisun and Central Valley. The area around Mare Island was likely occupied by Costanoan-speaking (Ohlone) people who occupied both sides of Carquinez Straits (Milliken 1995).

Establishing the pre-contact geographic territories of tribal groups and locations of villages is a challenging endeavor, however, because of the rapid cultural changes that accompanied Spanish expansion into the North Bay. Substantial information is, in fact, available in the form of Spanish and early American accounts, archeological data, and, in particular, the analysis of mission registers. The delineation of territories based on data from this period is complicated by the rapid loss of life in local villages, the wholesale movement of groups to the missions, or to more rural areas to escape missionization, and the formation of new Indian settlements as work camps for Spanish and American industries. Milliken (1978) assesses these data for the Napa Valley and describes three major tribes or villages, and the relative locations: the Canijolmano, in the vicinity of present-day St. Helena; the Caymus, in the Yountville area; and the Napa, along the lower reaches of Napa River below the present town of Napa. In addition, the Carquin occupied the lowest part of the River near Mare Island.

Evidence for the Napa Valley as a whole suggests that at least several thousand people inhabited the region at the time of European contact and delete that for centuries before. Exact estimates range widely, as shown in Table 1.

Table 1: Pre-contact population estimates for Napa Valley.

Author/Year	Estimate	Region
Menefee 1873	2,000	Suscol to Oakville
Rev. Orange Clark (n.d.)	8,000	Napa Valley
Cook 1956	4500	Napa Valley
Milliken 1978	3,000-4200	Napa Valley
Beard 1979	1650	Valley above town of Napa

Spanish contact

Southern Mexico fell under Spanish rule by about 1520. Over the next 250 years, however, the combination of intimidating tribes in northern Mexico, the physical barriers of deserts and mountains, and the lack of apparent gold in California prevented Spanish expansion northward. As a result, California Indian culture continued to flourish with little or no impacts from the transformations to the south until the late 1760s. Spanish presence in the Bay Area is thus notable both for its relative brevity yet high impact.

The northern part of San Francisco Bay experienced an additional delay, due to the natural barrier of Carquinez Straits and the Golden Gate (Milliken 1978). While missions, pueblos, or presidios were established in San Francisco, the Peninsula, the East Bay, and the South Bay during the late 1700s, tribes in the North Bay were still intact by 1810 (Milliken 1995). The weakening Spanish government and resistance of tribes in the North Bay contributed to a pause of nearly a half-century passed between the founding of the San Francisco Mission (1776) and the Sonoma Mission (1823). One effect of the persistence of indigenous culture in the North Bay was the adoption of native, rather than Spanish, names for most significant places, e.g. Marin, Napa, Sonoma, Petaluma, and Suisun.

However, the isolation of the North Bay from the Spanish colonial presence in the rest of the Bay Area was probably not quite as extreme as has often been reported. Father Altimira's expedition to determine a site for the Sonoma Mission is generally considered the first documented European exploration of the North Bay (Weber 1998), and George Yount is famed as "the first white man to set foot" in Napa Valley (Carpenter and Cosby 1938). However, Smilie (1975) and Milliken (1978) provide evidence of a number of previously undocumented Spanish excursions into the North Bay prior to Altamira's expedition of 1823. These contacts were recorded in the Mission San Francisco de Assis ("Mission Dolores") *Libro de Bautismos*, along with entries for new baptisms of Napa Indians. In addition, Smith and Elliott (1878: 2) describe a Spanish fort that was reportedly established in 1776 "a short distance northwest of Napa;" however, we have found no other confirming sources.

Changes following Spanish contact

While impacts to Napa Valley tribes have generally been considered to follow the establishment of the Sonoma Mission in 1823, examination of mission records shows that many of the effects came earlier. Spanish recruitment of North Bay peoples for work in the construction of Mission Dolores, and other settlements, resulted in the abandonment of the village at Napa by 1815. By 1824, the entire Valley south of Yountville had been essentially depopulated (Milliken 1978: 2.38-39). Even earlier impacts may have occurred: Milliken's analysis of demographic data (1978: 2.32, 2.35) suggests that the village near Napa may have been ravaged by the epidemic (type unknown) at San Francisco de Assis in 1795, nearly 30 years before the establishment of a Mission in Sonoma. Still unfamiliar with the manner in which communicable diseases spread, Napa Indians working at Mission in San Francisco likely carried the disease home with them on visits, or in an effort to flee the epidemic, rapidly infecting their entire community and anyone they met along the way.

Subsistence-based Indian land management techniques, which had likely played a major role in determining the character of the Napa landscape for generations, were thus in flux by the early 19th century. However, Indian habitation, and even management of the land was not easily halted. Despite intensive recruitment to missions and several decades of exposure to disease,

Indians were reported to be carrying out a controlled burn in the hills of Huichica or Carneros in 1823 (Altimira [1823] 1861). After the demise of the missions, Indians returned from San Francisco, San Jose, and Sonoma to Napa Valley and, despite large losses, survived the smallpox epidemic of 1838-39 (Heizer 1953) to the extent that Menefee describes perhaps 2,000 or more Indians in rancherias established on the Mexican land grant ranchos in 1843 (Menefee 1873).

Pejorative accounts of Napa Indians by Menefee, the author of Napa's first history, and others are common (e.g. "they encumbered the sidewalks, lounging or sleeping in the sun, half clad and squalid pictures of humanity in its lowest state of degradation" (Menefee 1873, describing Napa City before 1856)). These established a demonstratively negative conception of the local native peoples in the popular imagination (Beard 1979). Yet other, less well-cited accounts create a different picture of cultural resilience and continuity well into the American period. For example, an old-timer attested to seeing 3,000 Indians passing along the ancient trail from Napa Valley through Wooden Valley to Gordon Valley to attend a traditional dance in 1853 (Davis n.d.: 10). A large dance house was built just northwest of where the Yount Bridge crosses Napa River in 1866 (Davis n.d.: 11), re-establishing the traditional Wappo dance site at Yountville (Driver 1936: 85). However, by the early 20th century, censuses reported fewer than 100 Wappo (Calkins 1993). Yet many tribal members survived by moving north to Alexander Valley and Clear Lake, with groups existing through to the present in the form of, for example, the Mishewal-Wappo Tribal Council (Calkins 1993).

Mission and Ranchero Periods

Mission San Francisco de Solano (the "Sonoma Mission") was established in 1823, the final and northernmost of the California missions. The Sonoma Mission grew over the next 10 years, recruiting Indians from the local tribes, and developing agricultural fields and ranchos. These activities constitute the first direct, non-indigenous management activity in the Sulphur Creek area.

In 1833, the Mexican government initiated secularization of the missions. The prosperous Mission lands of California were legally intended for the Christianized Indians, but secularization effectively transferred land to Spanish and Mexican settlers over the following decade. Concern over the establishment of Russian bases at the ports of Bodega and Ross (Lightfoot 1991, 1997) led Sonoma to become the Mexican military headquarters for the North Bay and hastened divestment of land to settlers, mostly Mexican, to occupy the northern frontier of Mexico.

As a result, during the 1830s the Mission Rancho in Napa Valley began to be split up in 1836, and Rancho Rincon de los Carneros, extending northeast from Carneros Creek to the Napa River, was granted to Nicolas Higuera around this time. Higuera also received Rancho Entre Napa, contiguous to the north along the creek. Rancho Caymus, from Yountville to just past Rutherford, was granted in the same year to George Yount. In the next year, Antonio Ortega, the Administrator of Mission San Francisco Solano, was given permission to develop a rancho in the large area extending roughly from Napa to Yountville. This area was later granted to Salvador Vallejo (Smilie 1975).

While portions of the lower Valley were disbursed as land grants as early as 1836, the Northern part of the Valley was not divided into ranchos until 1841, when Edward Turner Bale received

the valley lands above Rancho Caymus, roughly from Whitehall Lane through Calistoga. As deeded by General Alvarado, the Rancho was bordered on the south by Yount and "on the other sides by the unchristianized Indians" (Alvarado 1841: 24). Rancho Carne Humana thus included the lower part of Sulphur Creek watershed, below the canyon openings on Heath and Sulphur creeks. Bale, an American citizen turned Mexican, appears to have transliterated the Indian tribal name *Canijolmano* into the odd name "Carne Humana" (Heizer 1953). Bale actually occupied the Rancho as early as 1838 or 1839, several years before the official deed (DeLaRosa 1852: 11; Yount 1852: 8)

David Hudson and John York acquired the land that is now the town of St. Helena in a series of purchases from Bale beginning in 1848. They returned some of the property back to Dr. Bale, in light of his financial setbacks, but this property ended up also lost to foreclosure (McCormick 1938: 4). The McCormick family acquired the ranch covering much of the upper watershed in the 1870s. Sons of the McCormick family married into the York and Hudson families, with the Learned/Perry families present-day descendents. Babe Learned is 86 years old and has lived in the watershed most of her life. The Garden family has also had a long-term presence in the watershed, with David, now 73, growing up on the ranch his family bought in 1940. Parcels have continued to be subdivided, with a more rapid pace reported in recent years.

Local settlement patterns

The Sulphur Creek watershed was clearly occupied and managed by the native peoples of the upper Napa Valley, the *Canijolmano*, whose territory was centered in the vicinity of Sulphur Creek. Sites of native artifacts are still common throughout the watershed (Learneds, pers. comm.). However, it appears that their permanent village was located not in the present-day town of St. Helena, but just across the Napa River. Heizer (1953) identifies a permanent village, "Annakotanoma," near the confluence of Sulphur Creek and Napa River, along the major Indian road corresponding to present-day Silverado trail.

American settlers began to build houses in St. Helena in 1853 (Paulson 1874: 3), and the early development of resort facilities on Sulphur Creek led St. Helena to become an important disembarkation point for decades. Established in 1855, White Sulphur Springs was Napa's first resort (Verardo and Verardo 1986: 88). The resort and vicinity are described by travel writers of the era:

The White Sulphur Springs are another fashionable resort. These are about six miles south of Calistoga, in the same range of mountains. They are in a deep gorge, so narrow that a strong man might throw a stone from one of the mountains that enclose it, to the other. A little babbling stream of clear, cold water ripples through the gorge over a pebbly bed, shaded by the foliage of broad oaks and drooping willows, forming quite a different scene to that about Calistoga. The waters are also different, issuing in a clear stream from the mountain side, at a temperature of about 80'. There are excellent hotel and bathing arrangements at these springs, but they are less frequented than Calistoga. (Cronise 1868: 181)

Here we are in the most delightful of spot of Napa County, and a short description will not be amiss: The White Sulphur Springs are situated in a very romantic mountain gorge. The hills on both sides are covered with timber and

underbrush, presenting a very wild appearance. The place first became noted in 1855, at which time a hotel was erected there. The beauties of the surroundings are principally natural, though many artificial improvements have been made . . . For pleasure seekers, the surroundings are unsurpassed. There are trout in the stream nearby, plenty of game in the neighboring hills . . . (Paulson 1874)

St. Helena became a center of commerce for the upper Valley and the wine industry in general, extending greatly in the last decades of the 19th century (Weber 1998: 245-247). During the most recent half-century, the city has also grown substantially resulting in an expansion of developed areas (defined as > 50% commercial/residential, minimum size 1 acre) between 1942 and 1993 (see Figures 5 and 6).

II: LAND USE

This section describes the land use history of Sulphur Creek watershed, divided into major categories of activities.

Aboriginal Subsistence and Resource Management

Given the population density and duration of human presence documented earlier, it is likely that controlled burns and other means of native management played a role in modifying the Sulphur Creek watershed prior to the Spanish and American eras. There is a growing recognition in the environmental sciences that the role of indigenous peoples in shaping the California ecosystem has been traditionally overlooked (Lewis 1973; Blackburn and Anderson 1993). Indigenous use of fire to modify grasslands, shrublands, riparian zones, forested areas, and even wetlands has been documented among tribes throughout North America (Lewis 1973; Stewart 2002) and clearly had the ability to alter vegetation cover at the landscape scale (Anderson 2002). Other techniques such as coppicing, aeration through tilling, transplantation, and selective harvesting were also likely employed to shape the character and extent of local vegetation types (Calkins 1994; Mathewson 1998).

Plant material used in basketry, cordage, snares, nets, and traps, weapons, clothing, structures, food, ceremonial items were managed with fire for specific quality, quantity, length, texture, and nutrient content (Blackburn and Anderson 1993; Mathewson 1998). In an analysis of Sierra tribes, Blackburn and Anderson (1993) estimated that more than 75% of plant-based items were made from just the epicormic branches or adventitious shoots – new growth which can be spurred by fire. In terms of influence over resources at a landscape scale, the successional trajectory of many systems was likely tightly controlled to maintain necessary the productivity of specific resources over vast acreages. For example, Kunkel (1962) estimated that an average Central California “tribelet”, consisting of some 850 people, would be dependent upon a territory of no less than 150 mi².

The cultural disruptions of missionization on indigenous culture in the Bay Area has resulted in native subsistence practices being less well-documented here than in many other parts of California. The use of fire in the region was nevertheless noted repeatedly by early European visitors in many parts of the Bay Area (e.g. Mayfield 1978; Stewart 2002). Deliberate setting of fires is actually fairly well-documented in the Napa region. In 1823, on the expedition to site the eventual Sonoma Mission, Father Altamira reported midsummer (June 28) Indian burning in the hills between Sonoma and Napa, probably in Huichica or Carneros. Translations of this event vary:

"We...proceeded in a north-easterly direction by a chain of hills. Although the grass had been burnt by the Indians of the neighborhood . . ." (Altamira [1823] 1861: 61)

"We went thus to northeast by one range of hills (which without delay were to be burned by the Indians whom we encountered) . . ." (Smilie 1975: 8)

Further evidence indicates that Indian burning in the Napa region was regular and purposeful, and well known to European settlers. Ethnographer Harold Driver (1936), who interviewed tribal elders in the 1930s, reported that the Wappo called the month of June "burn-the-valley moon," corroborating Altamira's observation. The 1836 treaty between Lieutenant Vallejo and the neighboring tribes, noteworthy as possibly the first formal treaty between the Spanish and California Indians, included the specification "...[T]hat they should not burn the fields (Smilie 1975: 61)."

Indian burning practices in the vicinity clearly continued at least through to the time of the treaty, although there may have been a gap prior to secularization, when Mission membership was highest. In addition to the effects of the treaty, the decimation of North Bay tribes by the smallpox epidemic of 1838, killing an estimated 60,000 to 70,000 Indians in the Mexican *Frontera del Norte* (Tays 1937), and the diversion of the Mission lands designated for the Indians to the Mexican land grants, probably caused native-directed fire management in the Sulphur area to cease by the late 1830s.

Although Vallejo was clearly not an advocate of prescriptive burns, there is some evidence that vegetation management through fire continued, at least in places, in the Napa region during the 19th and early 20th centuries. The Sonoma Mission apparently used light fires to keep the vegetation low in the vicinity of mission, as Father White accidentally burnt the church to the ground on June 25, 1896 while "burning off dry grass" (Smilie 1975: 119). Hunters on the McCormick Ranch regularly burned the underbrush to keep the hillsides open for hunting as late as the 1950s (Perry, pers. comm.), a continuation of the native practice which has been documented in other parts of the country to enhance both hunting and livestock forage (e.g. Cronon 1984; Wilkerson 2001). Jim Perry's conversations with second-generation hunters in the watershed provide some detail about this practice. Fires would be initiated at the bottom of hillsides and allowed to burn uphill. Fires would commonly take place in the winter so they would go out naturally. In the absence of fire management during the past half-century, hunters report that "hunting has gotten worse as the buckbrush [chamise] has come in" (Perry, pers. comm.).

Accidental fires also appear to have been fairly common in the western hills near St. Helena with, for example, a number of substantial fires reported during the 1870s and 1880s (Dillon n.d.). This is in sharp contrast to the past half-century. A recent compilation by the California Department of Forestry and Fire Protection maps dozens of fires throughout Napa County between 1951 and 2001, with few or no fires identified in the subwatersheds draining to Napa River from the west (CDF unpublished data).

While direct documentation for the immediate Sulphur Creek area is not available, it is highly probable that indigenous fire management took place in the Sulphur Creek prior to European

settlement. This practice likely caused the vegetation of the upper watershed to have a more open understory, and perhaps greater area of grassland/savanna, at the time of European contact than would have existed without indigenous management (Stewart 2002). Based upon conversations with local residents, vegetation management through the use of controlled burns may well have continued in a semi-organized fashion during the 19th and early 20th centuries.

A reduction in fires during the past half-century may well be responsible for the observed expansion in the extent and density of woody vegetation within undeveloped areas of the upper watershed during the past 50-70 years, although climatic factors could also play a role. The increase in woody vegetation can have significant ramifications on the watershed, including a reduction in stream base flow due to increased evapotranspiration (Whitney 1996, Cohen 1982). The potential for catastrophic fires that, in addition to the obvious human safety and economic concerns, can mobilize large amounts of sediment has probably increased with the cessation of repeated, light fires that would have tended to reduce fuel load.

Grazing

Grazing of hoofed animals can increase sediment and surface water runoff in a watershed by changing the vegetation cover and the properties of the soil. These changes take place by altering soil characteristics such as porosity and permeability, soil fauna, root depth and strength, and rain droplet interception and impact. However, most grasses are adapted to herbivory, hence the low placement of their apical meristems (centers of growth), among other traits (Hild et al. 2001). Many studies have demonstrated that careful application of grazing can be beneficial in restoring and maintaining native, perennial grasslands (e.g. Belsky 1992). During periods of drought however, the carrying capacity of rangeland systems can sometimes be exceeded, leading to overgrazing, exposure of bare soils, and loss of desirable forage species. It is also possible that early grazing activities on native ecosystems simultaneously adjusting to other changes (e.g. invasive species, reduction of fire) can result in particularly significant, long-term system effects. Understanding historical grazing practices is an important part of piecing together human influences on sediment and water production and change through time (e.g. SFEI 2001).

Introduction of Ranching to the North Bay and Sulphur Creek Watershed

In the fall of 1823, as the new Sonoma Mission was being established, livestock were brought from other Bay Area missions to start the Sonoma herds (Smilie 1975: 19). The year 1823-1824 is thus the beginning point for Spanish grazing practices and the introduction of non-native grazing mammals in the North Bay. (The Russian settlement further north at Fort Ross, which was established in 1812, was presumably the first introduction of cattle north of Carquinez Straits.) Native grazing mammals were plentiful at this time as well, as illustrated by the French traveler Duhaut-Cilly on his visit to the Mission in 1827: "the hills of this part of California, and the plains they leave between them, support an immense quantity of deer of prodigious strength and size" (Duhaut-Cilly [1827] 1999). Native grazers were hunted intensively, partly to reduce competition with domestic animals: "The many herds of large elk that roamed the nearby valleys were used for meat and manteca (butterfat) as well as tallow and hides, in these earlier years, to allow the domestic cattle to increase and also to clear the pasturage of wild animals (Smilie 1975: 26)."

By the end of 1823, the Sonoma Mission reported 180 head of cattle and 1100 sheep. At this point, herds were contained in the vicinity of the mission, but in 1824 cattle ranches were

established further into Sonoma Valley and to the east in Suisun Valley (the Santa Eulalia Rancho). The Mission ranchos extended further out into the adjacent valley and foothill grazing lands during 1825 and by 1827 ranchos were established in Huichica and Napa Valley. After a temporary high point and subsequent decrease in the first years, perhaps because substantial numbers of cows were killed for food, herds operated by the Mission increased steadily. In 1831, it was reported that the herds had become large enough now that older animals were regularly removed to manage herd size (Smilie 1975: 20-35).

Introduction of ranching to Sulphur Creek watershed

The Mission ranch established in Napa Valley by 1827 was apparently initially used for raising horses, while a special ranch was established in Suisun for cattle (Milliken 1975; Smilie 1975). It is not clear how intensively the upper Valley was grazed during Mission times. However, unfenced lands with no major stream barriers probably allowed some horses, and later cattle, to enter the Sulphur Creek watershed around this time. Because of its distance from the Sonoma Mission, though, the upper Valley was probably not as intensively grazed as other areas, such as Carneros, prior to secularization.

Post-secularization

Little specific information is available about grazing in the upper Napa Valley during the early 1830s and the years following secularization in 1834. During this time, prior to the distribution of the massive Mexican land grants, management of the landscape was relatively diverse and distributed. Indians released from the Mission were allotted small plots of land and their own herds of cattle and sheep, while other Mission officials, the Mission itself, and Vallejo all maintained herds. Some areas apparently went unutilized during this period. For example, we know that cattle and/or sheep were already using the Napa Valley and Carneros area during the Mission Period, but when Ortega received permission to use the former Mission lands in Napa adjoining Carneros he brought cattle from Sonoma (Smilie 1975: 62,63). Ortega also testified in the Land Case hearings for Entre Napa that in 1836 these lands (the eastern side of lower Carneros Creek) were presently "not occupied by the natives of the Pueblo nor by the stock or cattle under my charge, for the former have their rancho established in common and the latter the place of Soscol in the straits of Carquinez, where they trouble no one with their location." (Ortega 1836: 40-41). By 1838 or 1839, however, Higuera had a high density of cattle on his land (2,000 head/8,200 acres) and Leese brought in "four or five hundred cattle" soon after his first occupation of Huichica in 1839 (Vallejo 1852: 6).

With the establishment of the land grant ranchos, the number of cattle in the Napa Valley increased dramatically. While the entire Sonoma Mission lands contained about 6,000 head in 1834, Higuera had 2,000 and Salvador Vallejo 5,000-6,000 head of cattle on their relatively small properties by the end of the decade (Davis 1929: 31-32).

By the mid-1840s, the herds had grown even more dramatically, with the Nacional Rancho Soscol increasing from 5,000 to 14,000 head in about five years. William Davis, a prominent merchant in hides and tallow, notes the massive size of Vallejo's herds at this time, not even including the additional animals owned by Juarez, Higuera, and other neighboring ranchers:

The Nacional Rancho at Soscol had about 14,000 head of cattle, and a large number of horses. These cattle used to stray to a long distance along the margin of Suisun Bay. This rancho was under the control of General Vallejo from the

time he founded the military headquarters at Sonoma. He was virtually the owner of all the cattle on the north side of San Francisco Bay, which were originally reputed to be Mission or government property, but eventually he became the acknowledged proprietor of all these animals. Including Petaluma, Temblec and another rancho, the total of cattle on all these estates reached the enormous number of 50,000 head. This made the General the largest cattle owner in early California." (Davis 1929: 138)

Davis does not list Rancho Carne Humana as one of the important cattle producers in the North Bay, however, even though Bale has occupied the rancho since 1838. Bale nevertheless clearly raised cattle, as his claim was partly predicated on the statement that he was "the owner of a number of cattle and being in want of land in which to keep them" (Alvarado 1841: 24), and subsequent testimony indicated that he occupied the land with "cattle, horses, and sheep" (DeLaRosa 1852: 11-12). He also distributed hundreds of cattle in his will of 1849 (Bale 1849: 36). However, these numbers are small for a ranch of approximately 18,000 acres (Beck and Haase 1978). Bale is also noted in the land grant testimony as having substantial agricultural operations during this time. These concerns, as well as his famous sawmill and grist mill (Hoover et al. 1966: 241), may have predominated over ranching, as was common among Americans settlers.

Berryessa (Sharp 1867(?): 308) also reported that he and members of his family grazed about 1,000 head of cattle on Carne Humana around 1842-1850. While the location is nonspecific, it appears that he occupied areas to the north of Sulphur Creek. However, these cattle, again a relatively low number, may have been those referred to by McCormick, who did describe Spanish-introduced cattle roaming the valley upon his arrival in the late 1840s (McCormick 1938).

Estimates of Mexican era grazing density

Davis' descriptions of North Bay ranchos indicate a minimum overall regional density of at least 0.25 head/acre, or one cow in four acres by the 1840s (see *Carneros Creek Historical Ecology* report for more details). For comparison, Bancroft, in his summary of Mexican era grazing density, reports general land requirements per head of cattle during his era (circa 1880s) as ranging from 5-10 acres in California valleys and plains (Bancroft [1890] 1970: 55). Thus, while Mexican era grazing density in the North Bay appears to have been unusually high in general, areas closer to the Mission (such as Carneros, Huichica, Soscol) and areas of special focus (e.g. the cattle ranch at Santa Eulalia in Suisun) likely experienced higher intensity use. In comparison, ranching intensity during Mexican times appears to have been relatively lower in the northern part of Napa Valley, including Sulphur Creek. During the period prior to American contact, grazing practices likely did not have a major impact on sediment and water production in the Sulphur Creek watershed.

Grazing in the American Period

The agricultural value of the alluvial fan portion of the watershed led to its rapid agricultural development. Nevertheless, the overall amount of grazing in the watershed probably increased under American settlement with the development of ranches in the upper watershed.

The McCormick family established their ranch as early as the 1870s (Learneds, pers. comm.) and York developed a large stock ranch just over the ridge into Sonoma County (McCormick

1938: 11), presumably also in the later 19th century. Parts of the watershed have been cleared over the years to open up flats and less steep slopes for grazing, and stock ponds have been installed. The Learned family grazed sheep (as many as 1,000 head) as well as cattle. Ranching activity has decreased in recent decades. For example, David Garden, who ran 40 head of cattle 30 years ago, now has only 15 cows (Garden, pers. comm.; Learned, pers. comm.).

Given the heterogeneity of range habitat within the watershed, grazing density estimates were not developed for Sulphur Creek watershed. However, ranching has been a sustained activity in the watershed for over a century and may, in combination with associated clearing, have contributed to changes in hydrological processes and sediment production.

Introduction of Agriculture

The introduction of agriculture can dramatically change vegetation cover, with ramifications for sediment production and hydrologic processes (Whitney 1996). In contrast to grazing, growing crops involves varying amount of tilling, cultivation, and soil aeration. The styles of land surface change can vary substantially depending of the types of soil parent material, crops grown, the management of ground vegetation, vegetation for wind and sun protection, and use of water. In modern times, the use of chemical fertilizers and pesticides can be an important additional impact of agricultural practices.

Early establishment

The Sonoma Mission established fields in the 1820s to sustain the population of missionaries and military personnel, and to encourage Indian attendance. The Mission agricultural fields were considered quite productive by 1826. In that year, the fields produced 2,627 fanegas (~1.6 bushels) of grains, including wheat, barley, beans, peas, corn, and garbanzos from the "extensive irrigated fields south of the Mission," which were nevertheless probably limited to perhaps several hundred acres in size (Adams 1946, Bancroft [1886] 1963: 344).

European-style agriculture was initiated in the vicinity of Sulphur Creek by Bale about a decade later, probably in 1838 or 1839. Bale and local Indian workers developed a substantial agricultural operation that raised wheat, corn, beans and peas, fruit trees, and vines. When questioned "To what extent was the land in cultivation?", witness Jose De La Rosa replied "enough was cultivated to raise crops for the support of about 500 Indians then in his employ and dependent on him" (De La Rosa 1852: 11-12).



Figure 4. Vineyards in the Sulphur Creek Watershed circa 1933 (Carpenter and Cosby 1938).

American agricultural development

By the late 1840s, York and Hudson had planted relatively large and early orchards in the St. Helena area, with “plums, peaches, apples, and other fruits” (McCormick 1938: 10). Wheat fields and later vineyards followed, as a relatively diversified agricultural landscape developed. While Napa Valley vineyards expanded greatly in the 1860s and 1870s, travel writer Paulson describes both wheat and wine grapes as the dominant crops in the vicinity of St. Helena in the 1870s. The extent of grape-growing was reduced by the devastating effects of the vine louse *phylloxera* (in the 1890s and late 1880s). As a result, orchards and other crops were introduced or reintroduced, again producing a mixed agricultural setting in the lower watershed, which was still visible by the era of aerial photography (Figure 5).

In the upper parts of the watershed, hay farming has been common for generations (Garden, pers. comm.; Learned, pers. comm.) and in the lower hills toward the canyon mouths, vineyards have been developed at different times during the 20th century, as illustrated in Figure 4 (Carpenter and Cosby 1938).

The extent of urbanization, stream-associated habitat, and major agricultural categories circa 1942 can be seen in Figure 5. By 1993, nearly all of the orchards and grain of the lower watershed have been replaced, partly by vineyards, but mostly by urban expansion (Figure 6; Table 2). During the period 1942-1993, the area of vineyards in the upper watershed increased dramatically. Associated with the expansion of agriculture has been an increase in surface storage of water. As shown in Figures 5 and 6, approximately 12 acres of reservoirs or storage ponds were created by 1993, where there were none in 1942.

Table 2. Sulphur Creek Watershed Changes 1940-1993.

Land use or habitat type	ca. 1940 (acres)	1993 (acres)	% change
Vineyards	128	500	+291%
Developed	207	480	+132%
Hay, Grain, & Misc. Ag Production	199	0	-100%
Reservoir	0	12	--
Deciduous Fruits, Nuts & Olives	171	20	-88%
Grassland/Range	764	371	-51%
Riparian Canopy/Riverwash	60	47	-22%
Forest, Woodland, Chaparral	4,363	4,462	+2%
Recent Slide (Devil's Slide)	38	38	-
Total	5930	5930	

Note: Based on GIS analysis of 1940/42 and 1993 aerial photography, consultation with local residents, archival references, and limited "ground-truthing."

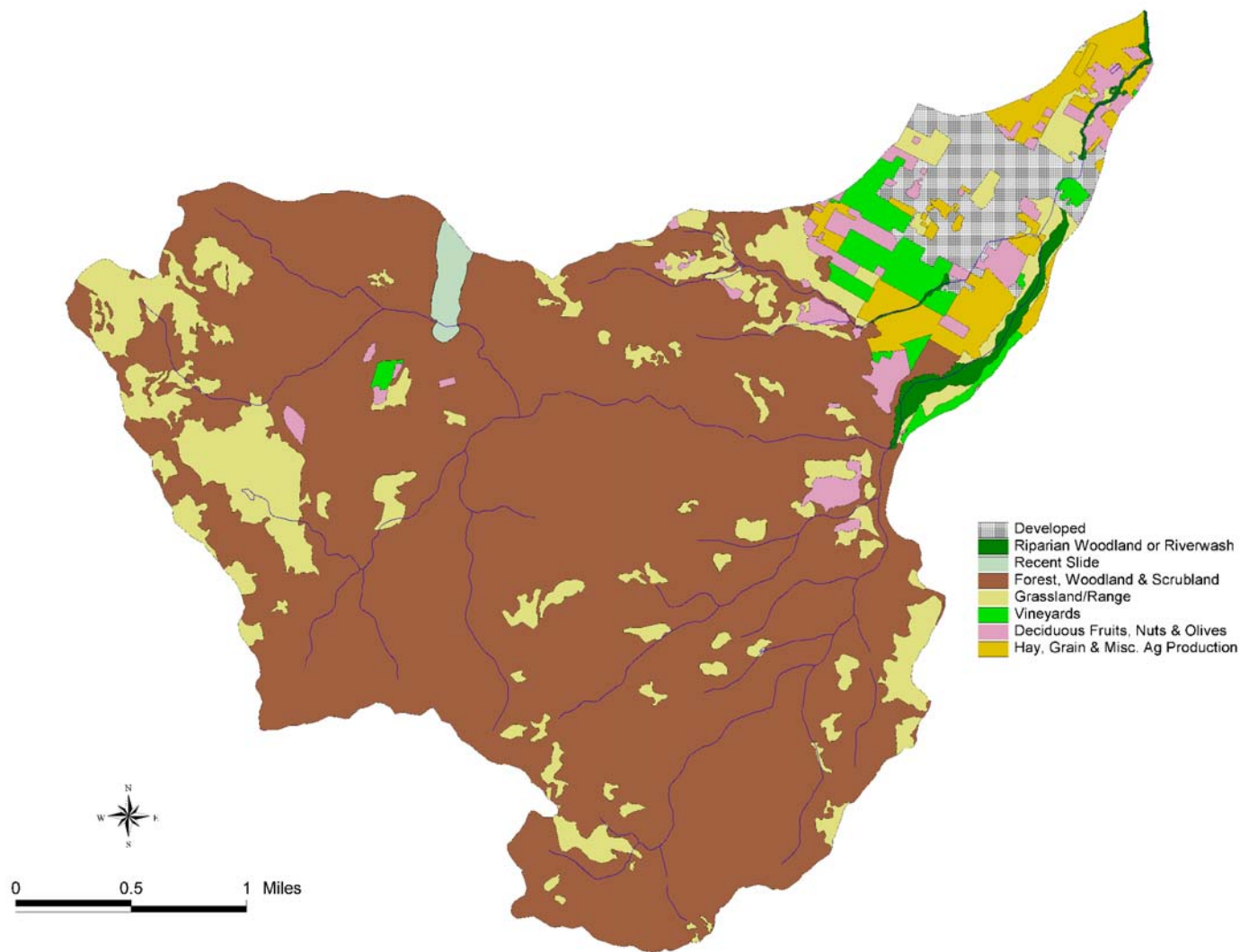


Figure 5. Land use and major vegetation types in lower Sulphur Creek watershed circa 1942, based upon interpretation of aerial photography and other sources.

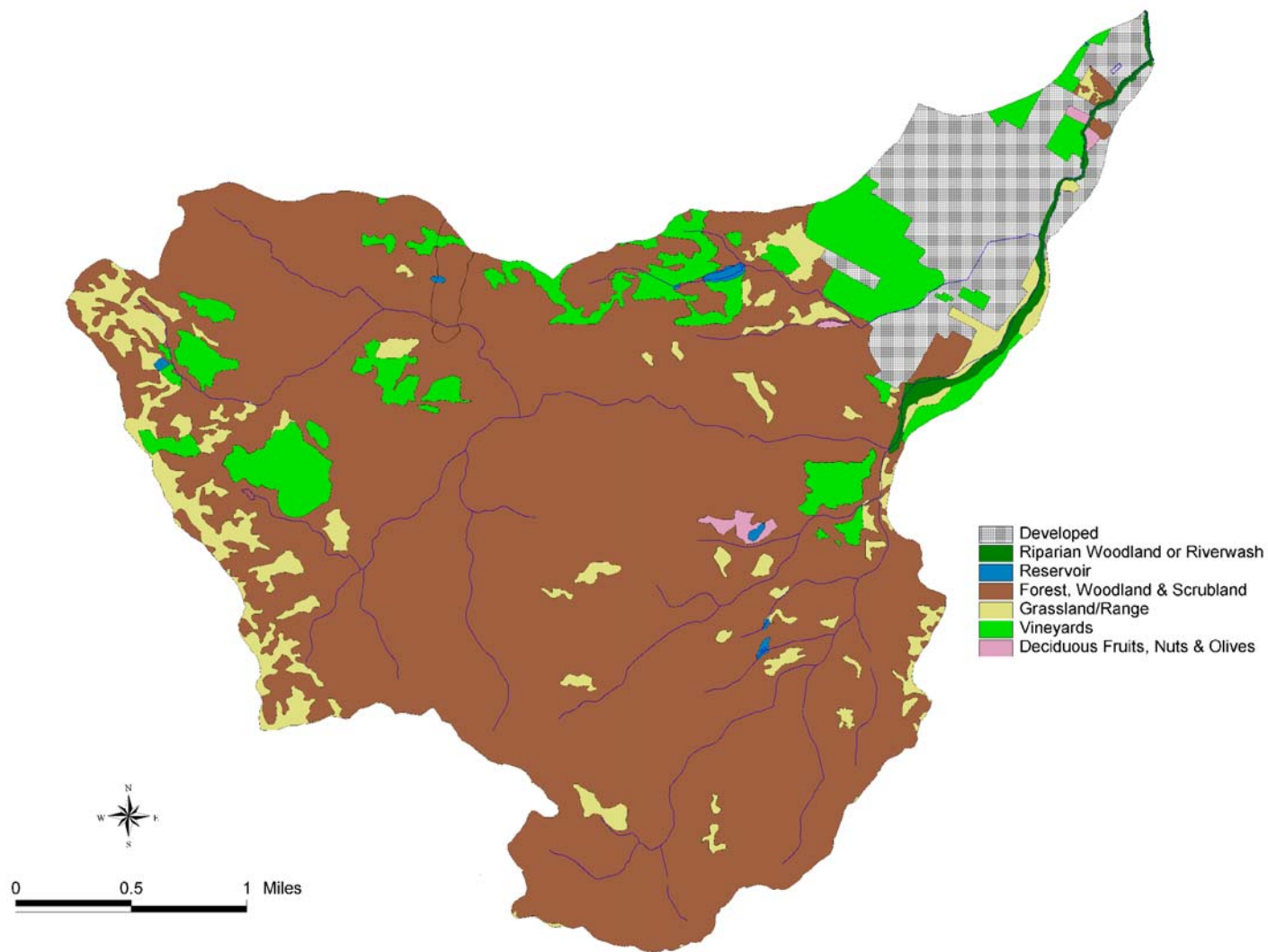


Figure 6. Land use and major vegetation types in lower Sulphur Creek watershed circa 1993, based upon interpretation of aerial photography and other sources. Grasslands/Range polygons adapted from those developed by UC Davis (Thorne et al. [in press]).

Woodcutting

Woodcutting can take place for variety of reasons, including the acquisition of lumber or firewood and the clearing of flat or less steeply sloped areas for grazing or agriculture. Immediate impacts to sediment production and runoff can be caused by the removal of vegetation cover, and longer-term changes in the distribution and abundance, and community composition, of vegetation types in the watershed can take place, with significant downstream effects (e.g. Whitney 1996: 266-271).

Woodcutting in the vicinity of the Sulphur Creek watershed is documented as early as 1848. Around this time, John York, one of the first two American settlers in the upper Napa Valley, built a house with shakes and timber from a giant redwood tree in the neighboring York Creek watershed. Later recollections estimated the tree at 25 feet in diameter. York is reported to have paid for the original purchase of his land by cutting redwood rails for fencing, likely in York and/or Sulphur Creek watershed's (McCormick 1938: 4, 6).

Woodcutting soon expanded beyond the valuable redwoods. By the 1870s, in fact, extensive amounts of redwood were being imported to the valley, local resources having been exhausted (St. Helena Star 1878a). Menefee (1879: 37), describing the mountains in the vicinity of the White Sulphur Springs resort, reports that "[r]edwood timber was formerly abundant upon the lower portion of this range, but it is now rapidly disappearing. The demand for building purposes and fencing has increased so rapidly that our supplies are now mostly obtained from Mendocino and Humboldt."

Madrone, manzanita, and oak were cut routinely during the second half of the 19th century and much of the 20th century. The opening of the upper valley to railroad transport, in 1866, allowing firewood to be traded beyond local needs, creating "an active trade in firewood", with commercial interests such as the Napa Wood Company purchasing thousands of acres of wooded hillsides (Young 1984). Cronise describes seeing 3000 cords of wood piled alongside the railroad for shipment to San Francisco (1868: 179).

As early as the 1880s, firewood in the Sulphur Creek watershed was routinely cut for local use, to serve the growing town of St. Helena. Harvesting was limited to the flats rather than the steeper hillsides (Garden, pers. comm.) but served a major local need. Babe Learned recollects her father cutting wood with a handsaw to bring "loads down to the ladies in town -- lots of wood, both for houses and stoves. They built more houses and cut more wood. There were 1200 people in town when I was a child, so there was a lot of clearing."

Clearing was also carried out, consistently during the past century and a half, for the associated benefit of opening up land for grazing (Garden, pers. comm.; Learned, pers. comm.).

In the early 20th century, professional woodcutters set up camps in the upper watershed, harvesting oaks on the McCormick Ranch, for example, continuously from the 1930s to the 1950s (Garden, pers. comm.; Perry, pers. comm.). David Garden, longtime resident of Heath canyon, describes large areas as "second growth."

More recently, extensive areas of woodland in the upper watershed have been cleared for the development of vineyards (Figure 5 and 6).

Evidence for the Sulphur Creek watershed indicates that woodcutting has been an important and extensive activity in much of the watershed since at least the late 1840s. Far from being pristine hillsides, the upper watershed has experienced in many places multiple cycles of clearing and regrowth. While supporting economic activity by producing building materials and firewood for several generations of local residents, the watershed has probably experienced increased runoff and erosion at times as a result of local woodcutting. Since landslide activity in the watershed appears to be dominated by natural processes (see further discussion below), this likely increase has probably not greatly affected the amount of sediment delivered to the stream. Impacts to the terrestrial ecology of the watershed are probably significant, however, and are discussed in *Hillside Vegetation*, below.

Channel-associated land use

Land use and land management changes in the vicinity of the creek channel have a greater chance of changing sediment and water production and influencing riparian vegetation. Stream crossings can provide a virtually unimpeded flow of both sediment and water to the creek. Early railroad and other crossings are often undersized for peak flood flows, causing debris jams, backwater effects, and flooding, with associated impacts to the channel (Collins and Ketcham 2001).

Gravel mining

Gravel mining has been a long-term use of the creek from the approximate canyon mouth to the vicinity of Main Street. The "Harold Smith & Son" Company harvested gravel from Sulphur Creek from 1910 to 1999, and was preceded by other mining operations at the same site in the 19th century, including rock for train track beds and the roadbeds of Napa city's street system (J. Varozza, pers. comm.; Weber 1998:194).

Channel crossings

The Napa Valley Railroad, connecting Napa Junction to Calistoga, was completed in 1866 (Weber 1998: 183), including a trestle across Sulphur Creek adjacent to Main Street. The total number of crossings on the creek (10; based upon current maps) is still relatively low (approximately one crossing per 1.2 miles of creek).

III: LANDSCAPE CHANGES

In this section we document specific changes in the geomorphic and ecological characteristics of the watershed that have taken place during the historical period described in the previous sections. We present evidence for observed changes in terrestrial vegetation, channel condition, and riparian habitat and discuss the implications for present-day watershed function. Topics are addressed in the form of pertinent questions developed through conversations with local residents and project team members, and based upon previous experiences in other watersheds.

Channel Plan Form and Riparian Habitat

Changes in channel plan form include channel redirection, filling, culverting, and loss of side channel or "backwater" features associated with the floodplain. These kinds of alterations can influence a range of critical fluvial characteristics, including channel gradient, base/peak flows, and riparian and in-stream habitat. On the valley floor and open plain, creeks can be directed

along completely new routes, creating new channel geometry and slope, which can affect the channel both upstream and downstream (Pearce et al. 2002). Documenting these changes is fundamental to understanding current trajectories in stream function.

Channel side vegetation, or riparian habitat, is an important aspect of the creek, protecting banks from erosion, potentially providing shaded summer rearing habitat for fish, and substantially determining its aesthetic character. Riparian habitat can be affected by changes in general environmental conditions, such as channel incision, reduction in groundwater level, saltwater intrusion, and climate change, as well as direct impacts from logging, clearing, grazing and other land uses. Because of these potential impacts, and because riparian trees grow relatively quickly, the current extent of riparian canopy can be greater or lesser than in previous eras. Understanding these trends may help identify the long-term processes determining the future of riparian trees along the creek.

Observations by the NRWEP in other parts of the Napa River watershed have identified stream reaches that have shown substantial increase in trees during the 20th century. Some reaches with few or no riparian trees circa 1940 have developed substantial canopies in the decades since that time. In some cases, both in the Napa Valley and in other Bay Area watersheds, this change over the past 60 years represents a reestablishment of historically-present habitat which had been removed by earlier land use (e.g. the alluvial plain section of Wildcat Creek 1900-2000, SFEI 2001: 24). At other sites the extension of riparian canopy appears to be an ecological response to a change in hydrological conditions (e.g. the downstream extension of riparian trees in the tidal reach of Wildcat Creek in response to reduced tidal prism 1850-1900, SFEI 2001: 22). Historical data from other parts of the Bay Area indicates that some of the smaller streams, of size similar to Sulphur, did not support continuous riparian tree canopies across the lower alluvial plain at the time of European contact.

A related concern in Napa, and other areas assessing goals for stream restoration, is determining the historical width, and subsequent loss, of riparian canopy. In many parts of the country, broad riparian tree canopies along low-gradient river systems have been reduced to narrow corridors with trees restricted to the area immediately alongside the stream as a result of clearing, channelization, and/or incision. Bay Area streams generally appear to have had narrow riparian corridors historically, however.

Is the braided channel pattern currently observed a product of historical land use or natural process?

Downstream of the canyon mouth, Sulphur Creek is currently characterized by a wide, braided channel (Figure 7) that extends nearly to Main Street. This channel morphology is unusual for Napa Valley streams. At the same time, this reach of Sulphur Creek has been the site of probably the largest long-term gravel mining operation on a local stream. The co-incidence of these factors raises the question of whether the current morphologic condition of the stream was created by gravel mining.



Figure 7. View of the braided channel reach of Sulphur Creek, looking upstream from Crane Street at the bridge crossing (location shown in Figure 8).

Katzel and Larsen (1999) discussed the relationship of gravel mining to stream form in this reach, but did not have information about pre-1940 stream condition or the duration and character of gravel mining operations. As a result, the authors were unable to resolve this question conclusively, but they did speculate that the current channel form might be similar to “natural” conditions (Katzel and Larsen 1999: 39).

As other researchers have noted (Katzel and Larsen 1999; Blake, pers. comm.), early direct overhead aerial photography also shows this reach as a similar broad, braided channel. We examined aerial photographs from August 1940 and May 1942. Both views showed a braided channel system, with rapid dynamics in the bar-channel configuration indicated by visible differences between the two images. A georectified photomosaic was created using the 1940/42 imagery (Burns and Grossinger 2003) and is compared to 1993 USGS DOQQ’s in Figure 8.



Figure 8. Comparison of the braided channel section of Sulphur Creek in 1942 (left) and 1993 (right). Dashed box indicates the area enlarged in Figure 10. Canyon mouth is at lower left, Main Street at upper right. Viewpoint of Figure 7 is shown in yellow.

Examination of historical maps provided illustrations of earlier channel form. The *Corps of Engineers, U.S. Army Tactical Map, Sonoma Quadrangle* (1933), which was surveyed in 1915, shows the route of Sulphur Creek below the canyon mouth as a stippled pattern curving to the northeast until it reaches the map's edge at the 38°30' latitude line (approximately the confluence with tributary Spring Creek; Figure 9). The stippled pattern, which conventionally represents sand, is in noteworthy contrast to the traditional "blueline" used to depict creeks in the rest of the map. The pattern appears to indicate here a broad, sandy channel, and also distinguishes this reach from other streams on the map, which covers the rest of Napa River watershed downstream to the Bay, and parts of Sonoma Valley.

A very similar depiction by the first United States Geological Survey map of the region, surveyed in 1896/99, extends evidence for the braided channel condition back to at least the late 19th century. The *Napa Quadrangle* (USGS 1902) also shows a dotted, broad pattern rather than a single blueline to depict Sulphur Creek below its canyon mouth (Figure 9). This pattern is unique to this map as well, which covers an even larger area of the North Bay.

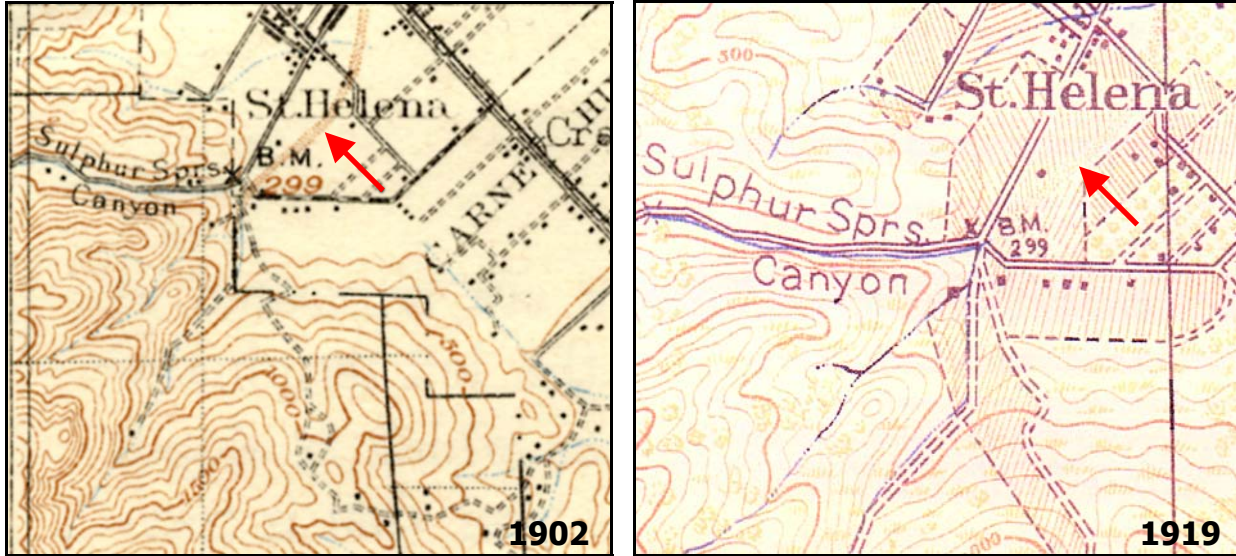


Figure 9. USGS 1902 and 1919 maps, surveyed in 1896/99 and 1915, respectively, use a stippled pattern to show the braided channel of Sulphur Creek. Spring Creek is the tributary joining Sulphur Creek above the words “St. Helena.”

Has the Creek Channel Been Straightened or Redirected?

Historical maps and the 1940s-era aerial photography indicate that, for the most part, Sulphur Creek has followed the same route across the alluvial plain through historical times. This finding is supported by the existing channel meander pattern, which generally displays curves indicative of natural form rather than ditching or channelization. There is one significant exception, however, where the route of the channel has been substantially altered -- the 2000 ft reach immediately upstream of Main Street. It is also likely that the lowest reach of Sulphur Creek has been straightened where it enters a constructed flood control channel (see further discussion below). Based upon conversations with local landowners, some sections of the stream in the canyons may also have been straightened over the years in the course of management for agriculture and flood protection.

In the reach immediately above Main Street, shown in Figure 10, a broad, braided channel configuration has been replaced with a narrow, straighter channel. Part of this conversion has involved the construction of a more confined channel along the route of the main channel within the former braided system (lower parts of Figure 10). The larger portion of this change, however, was the construction of a completely new channel to bypass a large meander of the braided channel system where it approached Main Street (center of Figure 10 images). The new channel was created by cutting northeast through agricultural fields to connect into an existing small ditch. The ditch, clearly shown in the 1942 photography despite having only a few trees at this time, was initially dug to divert Spring Creek, which had connected directly into Sulphur Creek. With the redirection of Sulphur, the Spring Creek ditch has been substantially widened to entrain the much larger Sulphur Creek.

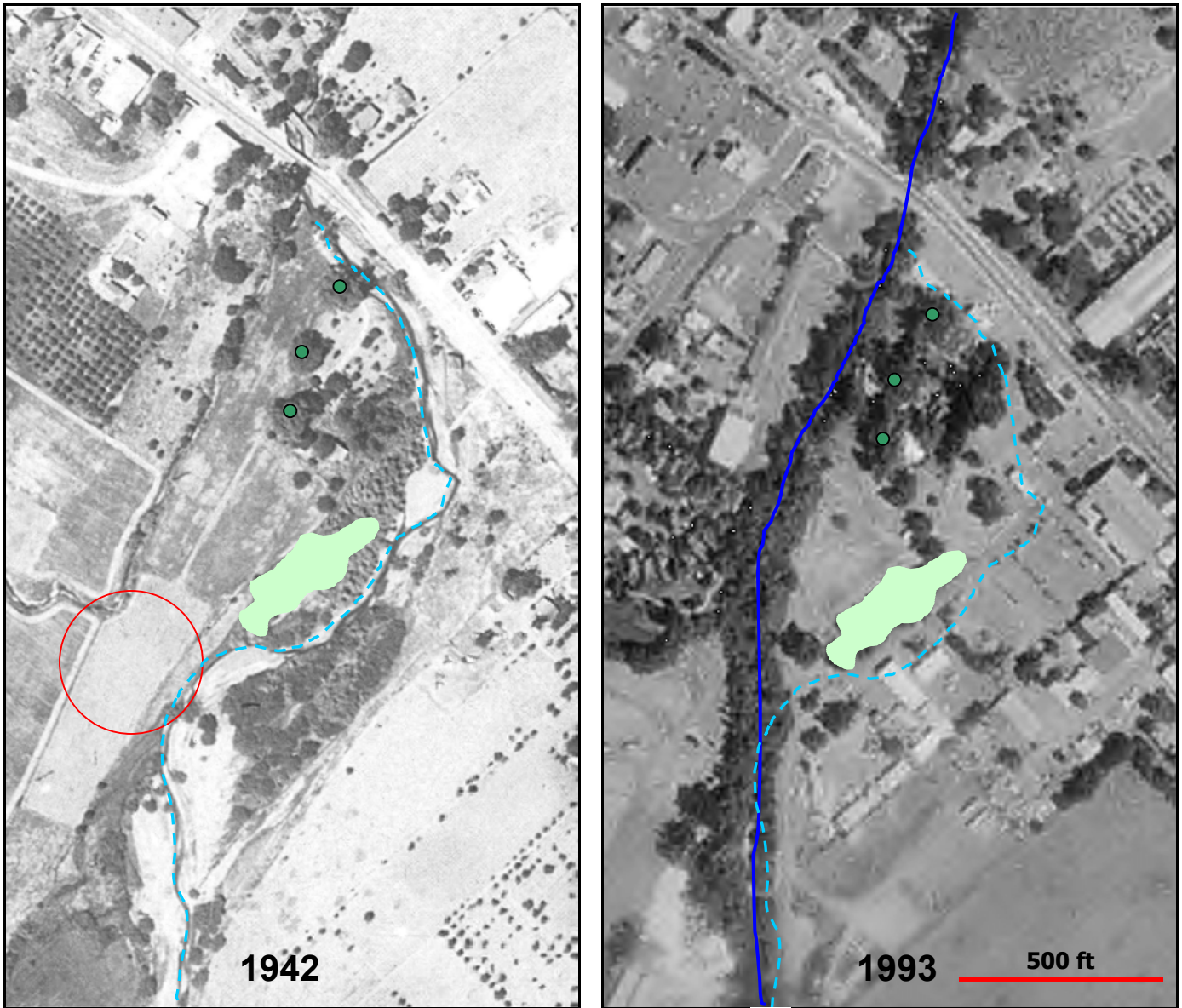


Figure 10. A 1942/1993 photo comparison shows the conversion of a braided channel system to a single thread channel, and the creation of a straight channel to bypass a large meander, on Sulphur Creek above Main Street. The main channel of the braided 1942 stream (left) is shown as a dashed blue line in 1993 (left). The new, straight channel, shown with a solid blue line, was made by connecting Sulphur to an existing ditch, the tributary Spring Creek (through the area circled in red). Since the change, the new channel has developed a narrow, tall riparian canopy that contrasts with the dispersed, low riparian habitat which characterized the earlier channel. Three large valley oaks (dark green dots) that previously occupied the alluvial plain to the left of the creek have maintained their position and are now on the right side of the creek. The area in stippled light green is an existing remnant of vegetation likely evolved from the former braided channel habitat.

It is not known exactly when this reconfiguration took place. However, the sign for Taylor's Refresher, the local hamburger joint built on top of the former creek bed, indicates that it was established in 1949, and the earlier braided channel form is documented as late as 1942 by aerial photography, bracketing the change to the mid-1940s.

This change in the basic characteristics of the stream less than 60 years ago has probably caused significant effects upstream and downstream, in addition to the direct effects upon this reach. The creation of the bypass channel has reduced the main channel length of this section from approximately 1850 feet to about 1300 feet. As a result, the stream gradient has likely increased and the function of this reach has probably changed from sediment storage to sediment transport. Increased stream velocities may also be responsible for downstream incision.

Has the Extent of Riparian Canopy Changed during Historical Times?

There are at least two complementary approaches to assessing historical changes in riparian tree canopy. The development chronology of existing riparian canopy can be analyzed by measuring the age of individual trees by tree coring methods. This approach only works where trees are currently present. Historical archival data can bracket periods of change and identify features no longer present. In this project, we performed historical archival analysis and assessed relative ages of existing trees in the field, as indicated by size. Coring of trees to verify riparian canopy chronology could be useful to further develop the findings.

Changes in riparian habitat along the valley floor reaches of Sulphur Creek have been substantial and non-uniform. These changes can be divided into several categories.

1. Conversion of low, in-stream braided channel habitat to taller riparian canopy.

As shown in Figure 10, an approximately 2000 foot reach of broad riparian habitat which likely comprised willows and other low riparian species has been removed from the stream. When this area was filled, circa 1942-1949, the stream was placed in an almost completely unvegetated ditch. In the intervening years, a narrow, taller riparian canopy has developed. While substantially different from historical conditions, the canopy has exhibited substantial growth, establishing a mixed species composition and height (Figure 11). The development of a riparian forest on this newly created section of the creek may be a useful illustration of the potential rate of establishment for local creek restoration projects. The development of this riparian habitat may also reflect its relative protection from immediate effects of adjacent land use, particularly in comparison to downstream sections (see below), indicating the value of adjacent habitats.

The previous route of the creek, circa 1942 and earlier, is almost unrecognizable. However, a thicket of willows and oaks occupying a lower elevation ground surface several feet below the adjacent plain has apparently persisted as a remnant of the former channel's riparian habitat (Figure 10, 12).



Figure 11. View looking downstream along Sulphur Creek above Main Street. The riparian corridor shown has developed after the stream was moved from its historical location to a new ditch, converting a braided channel network into a single thread channel.



Figure 12. Riparian thicket mapped in Figure 10, a likely remnant of the former braided channel riparian zone on Sulphur Creek immediately above Main Street. Note the step up to the adjacent plain at photo left.

Disturbance and potential reestablishment of low, in-stream braided channel habitat.

In the braided channel area immediately upstream from the above-described changes, intensive gravel mining has taken place for many decades. While the in-stream riparian habitat of a braided channel system is relatively fast-growing and typically subject to a high degree of natural disturbance by high stream flows and dynamic channel/bar movement, the continual disturbance of gravel mining likely reduced the development of persistent plant communities. This condition may be illustrated by the 1942 imagery, which shows a complex pattern of

vegetated areas and unvegetated bars in the area with no mining (Figure 8; unmined area enlarged in Figure 10), and little or no vegetation in the long area where gravel mining was taking place. With the cessation of gravel mining in 1999, vegetation patterns similar to the 1942 unmined section may be able to re-establish relatively quickly, and, in fact, local residents already report an expansion of vegetation in this area during the past few years. It should be noted, however, that substantial areas will likely remain bare of vegetation, as illustrated by Carpenter and Cosby's description of the "Riverwash" category (which included Sulphur Creek) in their 1938 soil survey of Napa County as "support[ing] little or no vegetation, although in some places, in areas protected somewhat from the full sweep of flood waters, willow, weeds, and grasses have become established."

2. Patchy re-establishment of riparian canopy.

Downstream, on the other side of Main Street and below the wide braided channel area, substantial lengths of stream had little or no riparian canopy circa 1942. In the intervening years, the stream corridor has become somewhat more wooded, but still has limited continuity (Figure 13). The more urbanized section upstream of the Pope Street Bridge is least well-developed, probably because of greater disturbance associated with adjacent land use. Compared to the vegetation on the new channel upstream of Main Street, which has developed during the same time period, the vegetation along this reach is particularly limited.

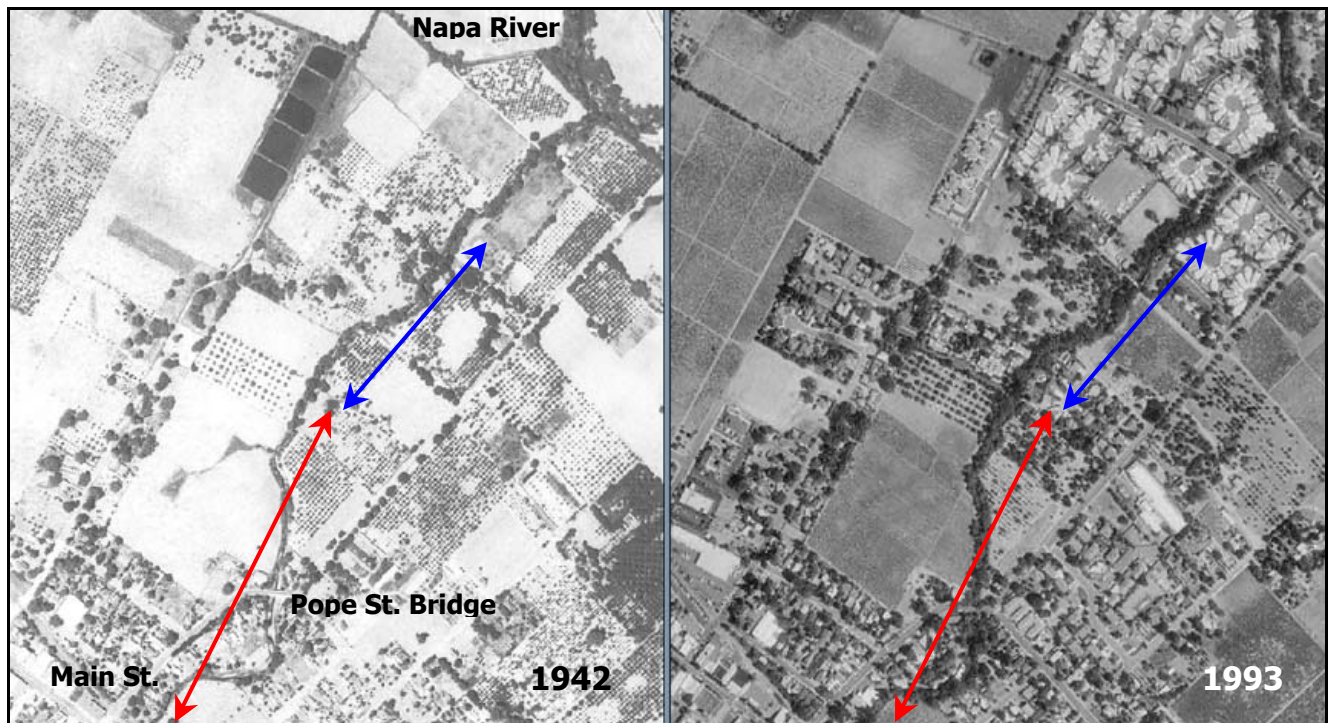


Figure 13. Differences in riparian canopy history: Sulphur Creek downstream of Main Street between 1942 (left) and 1993 (right). The reach indicated by the red arrow is currently composed mostly of relatively young trees (<50 years) that have developed alongside, or within, a channel that was almost completely devoid of vegetation in 1942. The reach marked by the blue arrow is characterized by much older trees (see Figure 14) that have likely been part of a riparian canopy continuously for the past few centuries. Very little riparian habitat

now exists in the lowest reach of the stream (upper right) where it is contained in a flood control channel before connecting to Napa River.

3. Older riparian canopy.

In the reach downstream of approximately Paulson Street, and upstream of the flood control channel, trees with greater trunk diameter and height are much more common in Sulphur Creek's riparian canopy (blue arrow, Figure 14). This reach has apparently persisted for a century or more without major direct disturbance.



Figure 14. Older section of riparian canopy on lower Sulphur Creek can be identified by the silhouettes of tall valley oak trees visible above the houses.

Has the Width of Riparian Canopy Changed during Historical Times?

As appears to be the case on most Bay Area streams, riparian tree stands along Sulphur do not appear to have formed a notably more broad zone of riparian trees beyond the visible channel during historical times. We have found no evidence that substantial areas alongside the stream were cleared of riparian forest to make way for grazing or agriculture. The nearby presence of valley oak savanna suggests that stream-influenced woodland did not extend widely beyond the stream channel. However, the width of the riparian/riverine zone in the braided channel reach has been substantially reduced by creation of the bypass channel and some filling apparently associated with the encroachment of urban and agricultural land use (see Figures 5 and 6).

Channel Connectivity

Has the Channel's Connectivity across the valley floor into Napa River changed?

Recent findings of the NRWEP suggest that many of the tributaries to Napa River did not maintain continuous channels across the valley floor until the creation of ditches in the late 19th or early 20th century. For Sulphur, no specific evidence has yet been found to suggest that the creek did not maintain a clear channel across the valley floor during historical times. However, it is nevertheless possible that Sulphur did not maintain a distinct channel in its lowest reach and thus was discontinuous with the Napa River main stem before European modifications. This change, which has not yet been documented but may be illustrated by historical maps, would have caused significant upstream effects due to the change in base level and associated adjustments in stream gradient and sediment transport.

Stream Fish

Steelhead have been reported consistently throughout the creek's recorded history. Paulson (1874) described "trout in the stream nearby" when visiting the White Sulphur Springs resort. Fishing was common to the degree that local stocks were considered potentially threatened, as illustrated by a St. Helena Star article published in March 1876. The article, "Pot-Hunters, Beware!", emphasizes that "[t]he law prohibiting the catching of trout in any of our mountain streams" prior to April 15th "is absolutely necessary for the preservation of the very existence, even, of trout in our streams, and ought to be rigidly enforced. We learn that persons in St. Helena and vicinity are constantly violating the law, and rapidly catching all the trout for several miles around" (St. Helena Star 1876). Not all of these fish are necessarily native rainbow trout-steelhead, however, as the California Fish Commission was stocking Napa River with "land-locked salmon and Eastern brook trout" during this era (St. Helena Star 1878b)

Stream surveys conducted by the California Department of Fish and Game in 1941, 1958, and 1980 report definite or probable rainbow trout/steelhead and are summarized in the Channel Geomorphology Report. Longtime residents recollect steelhead in the creek during their childhood and through to recent times, although with some declines (Garden, pers. comm.; Learned, pers. comm.). One resident who remembers catching a steelhead 20 inches long in 1940 notes that fish of that size are not found currently. In summary, there are a number of local residents with long-term experience with the local steelhead run. They testify to its persistence through recent history and are engaged in its improvement.

Sediment Supply

Is the current sediment supply to the braided channel reach significantly different from historical levels?

Sediment supply is a key factor determining channel form, and the channel's associated ability to provide for fish habitat and the transmission of floodwater. Determining the degree to which the channel pattern of lower Sulphur Creek is the product of natural or anthropogenic fluvial processes is fundamental to understanding potential restoration scenarios, as well as the risk of future flooding.

As discussed earlier, the braided channel pattern currently observed downstream of the canyon mouth is documented as far back as 1896-1899. Aerial photographs from 1940 and 1942 show that the braided channel extended further downstream than currently, approximately to Main Street, and illustrate a similar braided system, despite gravel mining prior to that time. Soil

surveys carried out in 1933 (Carpenter and Cosby 1938) and 1965-73 (Lambert and Kashiwagi 1978) confirm the presence of "Riverwash" deposits above Main Street, extending several hundred feet up Heath Canyon. These documents confirm the general width observed in the 1940s, suggesting that the depositional area has been consistent in extent during this time. This reach of Sulphur Creek is also the only "Riverwash" area depicted in Napa Valley.

Observations of stream character throughout the valley by the NRWEP suggest that the broad, braided channel of Sulphur Creek is, and was, a unique feature in the Napa Valley. Probably not coincidentally, Sulphur Creek appears repeatedly in the historical record as an important source of gravel for major local construction efforts. Sulphur and Conn Creek (Garden, pers. comm.; Weber 2001: 248) are the only tributaries for which we have found, so far, evidence of substantial historical gravel mining operations. Sulphur Creek is the only Napa Valley tributary to have supported a substantial gravel mining company for most of the past century.

Conversations with local residents involved in the gravel mining business confirm the obvious: harvest of gravel was made possible by annual replenishment from the watershed. As a result, unlike gravel quarries utilizing ancient river deposits, mining activities on Sulphur Creek did not create a persistent "pit." Because of the importance of the sediment to commercial activities, and the willingness of local landowners to share their knowledge, we were able to gather some detail about annual sediment production. Quantities on the order of 40,000 to 50,000 cubic yards of material were harvested annually, with production diminished substantially in occasional dry years, to perhaps 10,000 to 20,000 cubic yards (H. Varozza, pers. comm.). The Varozzas describe that "every year there would be a deposit of a foot or a foot and a half" across the bed, from which they would pull material. The activity was regulated by California Department of Fish and Game, at least in recent decades, who would determine where to carve a channel to direct flow in the winter. It was also noted that despite a number of different creek configurations created at different times, "pretty much every year at the end of the year it was very similar, it had its own pattern" (J. Varozza, pers. comm.).

The area of the braided channel reach is on the order of 150,000 square yards, but gravel mining was restricted from the stream edges, so an estimate of potential mining area might be roughly 100,000 square yards. Given an annual deposition and harvest of 1-1.5 feet, 30-40% of this area of the channel might have been harvested, suggesting the removal of active bars rather than deeper bed sediments and reasonable agreement between the estimates.

Sulphur Creek continues to supply and deposit substantial amounts of sediment in this reach. Local observations suggest that as much as 5 feet of material has built up in the channel bed since the cessation of gravel mining in 1999 (Varozzas, pers. comm.). To what degree is this volume of sediment production "natural"?

The noted "Devils Slide" on the Northwest Branch of Sulphur Creek, which was re-activated in 1982-83 (Blake, pers. comm.), and was reported to be inactive in 1978 photography (Katzel and Larsen 1999), nevertheless is clearly active in 1940 and 1942 photography (Figure 15).

Earlier information about watershed sediment production was found in the form of the General Land Office survey carried out in November 1869 to establish Township and Range section lines. Deputy Surveyor DeWoody (1869: 239) encountered a slide at precisely the current

position of Devil's Slide on his survey heading east along the south boundary of section 34, 7N, 6W.

At 29 chains, he describes: "Edge of sliding bank about 200 ft. high, and descend along face of same."

At 37 chains, he reports: "Bottom of same, enter Sulphur Creek, course southeast and ascend."

This information indicates that the slide is active and obvious, with a clear western edge in 1869. They measure 8 chains, or 528 feet, to cross the slide, which is now about 400 feet wide at that point. Interestingly, they describe intersecting Sulphur Creek where it flows southeast, which may correspond to the nearby slide currently observed slightly downstream of Devil's Slide (Katzel and Larsen 1999), indicating that it was a single, continuous feature.

While Devil's Slide was active as early as 1869, prior to modern land use, some new land use activities had been initiated in the preceding years. As discussed earlier, woodcutting in the Sulphur Creek watershed began as early as the late 1840s with logging of redwoods and clearing for firewood.

The Sulphur Creek watershed is underlain by the Franciscan Formation, which is naturally prone to failure and erosion (Fox et al. 1973; *Channel Geomorphology* report). Landslides and other mass wasting processes would be expected on this geologic substrate, even in the absence of management activities. The other Napa River tributary watershed dominated by Franciscan geology is Conn Creek, also a site of historical gravel mining with annual replenishment. Mary Grigsby, the owner of this site, indirectly confirmed this point when she fought against the Conn Creek Dam in the 1940s, saying that the dam would trap all the gravel and destroy her business (Weber 2001: 248).

The geology of the Sulphur Creek watershed and associated mass wasting during the Holocene is probably responsible in large part for the creek's substantial alluvial fan, one of the few large fans formed on Napa Valley tributaries (Kunkel and Upson 1965: 35) and made it a natural town site for St. Helena -- above Napa river flooding and in the shade of valley oak trees occupying the better drained fan soils.

While landslides are naturally common to the watershed, and the largest current slide predates almost all American land use activities, it should be considered that current management practices in the watershed such as clearing, road construction, and changes in drainage and water storage can activate new slides in a landscape with high potential for hillslope failures.

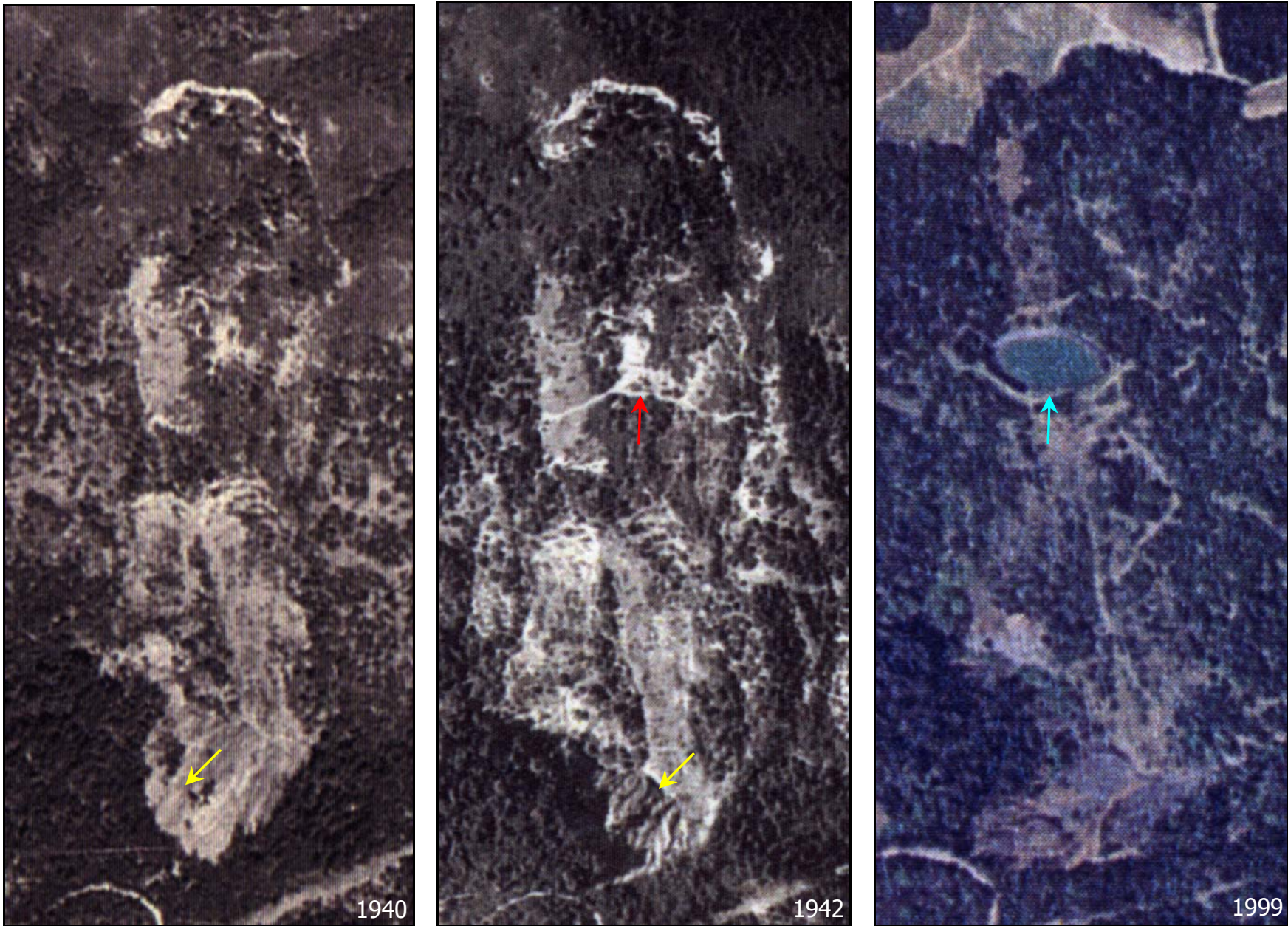


Figure 15. Devil's Slide, on the Northwest Branch of Sulphur Creek. There appears to be evidence of increased erosion gullies at the toe of the slide (yellow arrows) between 1940 and '42 (despite the increased shadow in the 1942 image due to wet winters in the early 1940s following a decade of drought (see Figure 3) and a road installed near the upper center of the slide (blue arrow). For location of slide with

Channel Depth

Has the channel bed depth changed significantly during recent or historical times?

Changes in channel depth influence the suitability of habitat for fish through changes in sediment storage and production. They can also alter the intersection of the channel thalweg with groundwater, affecting riparian vegetation and the seasonal persistence of pools and flow. Rapid channel incision can reduce the stability of stream banks causing the erosion of adjacent land and loss of riparian trees.

Incision/aggradation was not identified as a major concern at the outset of this project; however, some preliminary information collected here suggests that further investigation may be warranted. As discussed above, observations by local residents indicate that substantial aggradation has taken place in the braided channel reach during recent years, since the termination of local gravel mining. These observations are corroborated by sediment deposits which now cover the base of the Crane Street Bridge in this reach. Further downstream, the Main Street Bridge also displays evidence of aggradation.

Downstream of the Pope Street Bridge, which does not exhibit significant net incision/aggradation since its construction in 1908, we observed evidence of incision. In particular, many of the large riparian trees comprising the reach with older riparian canopy displayed substantial undercutting with exposed rootwads.

Interviews with local residents on the lower part of the stream can help elucidate whether substantial incision has taken place in recent decades, and a continuous geomorphic survey may help identify the degree and upstream extent of incision. One possible mechanism for incision during the past half-century would be upstream adjustment of bed elevation in response to the creation of a deeper flood control channel at the stream's confluence with Napa River. Further incision resulting in a deeper channel may affect safety and property concerns, and could hasten the loss of the grand riparian trees that represent a significant aesthetic element of the surrounding neighborhood. Effects of proposed new projects in the braided channel and flood control channel reaches should be considered to avoid causing additional incision in the lower reaches of Sulphur Creek.

Valley Floor Habitats

The valley floor adjacent to lower Sulphur Creek comprises a relatively small portion of the Sulphur Creek watershed. However, changes in this area can directly affect the quantity, and in particular, the quality of water delivered to the main channel. The valley floor portion, which includes much of the town of St. Helena, is where most of the watershed's human population resides. Changes here thus directly affect the quality of life of many watershed residents.

A major increase in urbanization has taken place in recent decades, as illustrated by 1942 and 1993 aerial photographic data (Figures 6, 7). This has resulted in the loss of substantial amounts of agricultural land in the valley floor portion of the watershed. Increased development and associated urban runoff will have negative effects for stream water quality unless well-managed.

Sulphur Creek historically flowed through a large complex of valley oak groves with intervening grasslands and occasional seasonal wetlands (NRWHEP, unpublished data). St. Helena appears to have been the site of one of the largest valley oak groves in the Napa Valley and this may

have been partly responsible for its attractiveness as a site for European settlement. The park-like oak savanna, with seemingly perfectly-placed giant oaks, was marveled at by visitors and settlers, but rapidly diminished as a result of clearing for agricultural land (e.g. McCormick 1938). However, recent mapping indicates that several dozen large valley oak trees still survive as remnants of the historical oak savanna in the lower watershed, as well as additional younger trees (NRWHEP, unpublished data). These features may be considered valuable components of the watershed's natural heritage and could be maintained by efforts to preserve the older trees and enhance the growth of younger, replacement trees.

Hillside Vegetation

Hillside vegetation plays a major role in determining the amounts and timing of sediment and water supplied to a stream. Changes in vegetation can alter the proportion of rainfall that is intercepted or transpired and the ultimate amount of runoff received by the channel network. Northern California hillsides supporting native brushland or woodland vegetation are often assumed to have persisted relatively unchanged during historical times. Local investigations often reveal significant impacts, however. Research in the neighboring Sonoma Creek watershed, for example, has shown many of the hillside forests are actually second or even third growth features (Dawson pers. comm.).

Has the hillside vegetation undergone significant changes during historical times, or has it remained largely unaffected?

In the Sulphur Creek watershed, intensive land use in the upper watershed, including logging and clearing for both firewood and grazing, is well-documented since the 19th century. Notable changes are also visible in 1942/1993 aerial photographic comparisons, illustrating two distinct trends (Figure 16). First, substantial areas of woodland, scrubland, and grassland have been converted to intensive agricultural use during the past several decades (Figures 5 and 6). For example, the area of grassland/range habitat has decreased by approximately 50% during this period (Table 2). Second, within the areas not managed for agriculture there has been a general increase in the spatial extent and stand density of woody vegetation. Many areas of open grassland or savannah, some of which were apparently created by woodcutting in the earlier part of the century, have been subsequently invaded by brush and trees and converted to woodland. It is likely that this is due, at least in part, to a reduction in fire frequency during the second half of the 20th century. Because of these two counter-opposing trends, the total area of woody vegetation (forest/woodland/scrubland) remains similar but its distribution and character have changed substantially.

Changes in the vegetation of the upper watershed have clearly been dynamic since European settlement and potentially before, under native management. It may be important to recognize these changes and the current trends in the watershed, as a basis for determining longer-term goals for the habitats of the upper watershed. Some of the potential negative impacts of current trends include the following. The increase in agriculture and associated water storage, and the expansion of woody vegetation, are both likely to increase evapotranspiration from the watershed (Cohen 1982) potentially reducing base flow in Sulphur Creek. The expansion of woody vegetation, which was previously maintained in a more open condition to increase hunting success, is likely to continue and typically reduces the amount of deer and other desired wildlife. In addition, continued expansion in undergrowth or "buckbrush" has the potential to increase the risk of catastrophic fire. Controlled burns in the non-agricultural vegetation areas of the upper watershed might be an effective way to manage these linked watershed concerns.

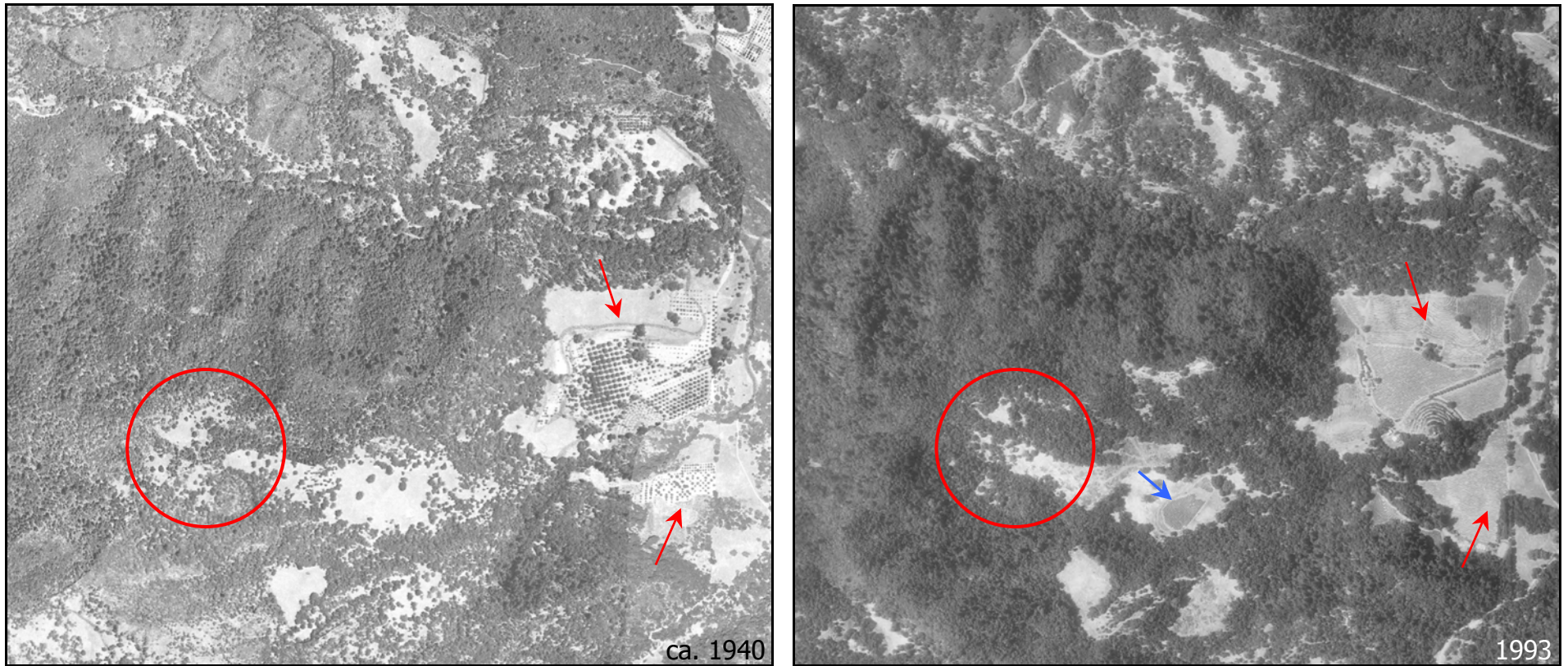


Figure 16. Landscape patterns in the upper portion of Sulphur Creek Watershed have changed in several ways since the 1940s. One of the most notable changes has been an increase in stand density and canopy cover (as indicated by the red circle, also apparent in the bottom-left corner of the photos). Forest stands have increased not only in the number of trees per acre, but also in the brushy understory, which has encroached onto the grassland/range areas in many areas. Another important change has been a replacement of grasslands and deciduous fruit, nut & olive orchards with vineyards (red arrows). Vineyards have expanded in both size and distribution within the watershed. With the exception of a small vineyard off the north fork of Sulphur Creek, 1940s vineyards did not extend significantly beyond the southwestern end of Spring Street, whereas 1990s vineyards extend to the uppermost watershed boundary. The blue arrow indicates an agricultural reservoir, which increased in number from 0-8 by the 1990s.

MANAGEMENT IMPLICATIONS

This report summarizes the sequence of major land uses within the Sulphur Creek watershed and associated landscape changes over the past two centuries. Land management has changed dramatically a number of times during this period, with one of the major shifts occurring in the past several decades.

Implications for the management of the watershed are listed below.

1. The broad, braided channel reach of Sulphur Creek is a natural phenomenon that is a unique feature in the Napa Valley. This persistent channel pattern has been created by relatively high sediment production rates in the watershed associated with the inherently erosive Franciscan Formation. The braided channel reach of Sulphur Creek contributes substantially to the diversity of stream habitat within the Napa Valley.
2. Sediment produced by the watershed has effectively balanced long-term gravel mining, which has been a significant activity since the latter 19th century. Observations since the termination of gravel mining indicate continued substantial deposition, with aggradation of as much as five feet in the past three years. It is expected that the stream bed will continue to aggrade without the removal of sediment from the braided section. This could lead to increased flooding and the risk that Sulphur Creek could reinitiate fan-building, reoccupying other parts of its alluvial fan.
3. With the cessation of gravel mining, additional sediment may be transported to the confluence with Napa River, particularly if engineering adjustments are made to reduce sediment deposition in the braided reach. The potential for backwater deposition in lower Sulphur Creek should be considered, particularly in relation to proposed flood control efforts.
4. Landslides are dated back to at least 1869, in the case of Devil's Slide. Landslides are a natural process within the watershed, but may also be triggered or exacerbated by land use activities. Clearing has been common in the watershed during historical times, but has increased substantially with the extension of vineyards into the upper watershed in recent decades. The extension of agriculture, and associated changes in drainage patterns, has the potential to trigger additional sediment production and watershed managers should be careful to avoid triggering new slope failures.
5. The density of woody vegetation in the upper watershed has increased substantially during the past 60 years, likely as a result of decreased fire frequency. This has probably increased the risk of significant fire in the watershed. A number of other valuable attributes of the watershed may also be affected by this change, with possible effects including reduced wildlife habitat, less accessibility to people, and decreased base flow in the stream. Controlled burns may be considered to address some of these concerns.
6. The braided channel section of Sulphur Creek has been both narrowed and shortened over the past 60 years, decreasing a significant area of sediment deposition/storage and reducing associated aquatic and riparian habitat.

7. The creation of a single thread channel in the presently braided reach would actually make the channel less similar to its historical, or “natural” character. Such a constructed channel may have difficulty moving the substantial sediment loads through this section and has some potential risk of failure.
8. The creek's riparian corridor on the valley floor is heterogeneous due to a diverse history of channel changes. Several distinct reaches were identified, with specific associated concerns:
 - a. Downstream of Main Street and upstream of the Pope Street Bridge, efforts should be made to enhance the limited riparian overstory;
 - b. On the lower creek upstream of the flood control channel, an older section of mature riparian canopy was identified. Many of the trees in this section, which provide shading for fish passage and aesthetic value to the neighborhood, are substantially undercut. Further incision could cause a high rate of fall into the creek;
 - c. A section of new riparian canopy that has developed on a reach of the stream constructed less than 60 years ago suggests the potential success of riparian habitat restoration with adequate protection from adjacent impacts.
9. Qualitative observations of both incision and aggradation in the lower reaches suggest that the creek is actively responding to recent changes in its management, such as the termination of gravel mining and, perhaps, the original creation of the existing flood control channel. Further study is appropriate to assess these responses and the potential responses to current and future projects. A continuous stream survey of bed elevation and bank erosion may be useful to assess the preliminary observations of streambed change. Projects proposed in the braided channel and flood control reaches should be considered with regard to their effects on incision/aggradation in the reaches upstream and downstream.
10. The historical valley oak savanna that characterized the lower watershed still exists as remnant trees within the town of St. Helena. This element of the community's heritage could be enhanced and maintained for future generations by restoration activities.

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