Summary of existing information in the Watershed of Sonoma Valley in relation to the Sonoma Creek Watershed Restoration Study and Recommendations on How to Proceed

Prepared for the U.S. Army Corps of Engineers, San Francisco District
by the
San Francisco Estuary Institute and Sonoma Ecology Center

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Executive Summary

This report illustrates the variety of data available in relation to the future possibility of carrying out projects that aim to reduce flood hazard and restore or enhance environmental values in the Sonoma Creek watershed and Baylands.

This report is meant to be a starting point for information and recommendations rather than an endpoint. Although it contains over 150 pages of text, figures and tables it does not claim to be complete. Instead it aims to stimulate discussion by asking as many questions as it answers. This report is one of two documents. The second document is the verbatim minutes of the technical advisory committee meeting held at Atwood Ranch on August 30th 2000. Both documents are available from San Francisco Estuary Institute (SFEI) or from the SFEI web page (www.sfei.org) in pdf format.

There are five strong principles that have been reinforced during this review of information and during the technical advisory meeting:

1. That there be a strong community involvement, and this should drive the process of identifying potential actions. Community involvement includes:
   - *Gathering and recording community opinions on what, if anything, should be done.*
   - *Community representation from all over the watershed and this should be encouraged at all stages, because the solutions are likely to involve the whole watershed community.*
   - *Gathering and recording both historical and contemporary environmental knowledge.*
   - *Consultation throughout the science and decision making phases.*
   - *Education about why any scientific, engineering or management alternatives are proposed so that the community is able to help make choices.*
2. That the approaches to flood mitigation and environmental restoration consider the watershed as a whole. No single project will be able to achieve any substantial reduction in peak flow, total flood event discharge or flood routing. Instead, many small projects taking a variety of approaches across the whole watershed and Baylands would be more

likely to provide ecosystem benefits, as well as achieving a reduction, or at least no increases, in flood risk in a bottom-up / top-of-the-watershed down approach.

3. That any Baylands projects consider the Napa / Sonoma Marsh as a whole. The Napa Sonoma Marsh system in linked closely both in space and time. Any changes in one "side" of the system are likely to affect the other "side" (physically, chemically and biologically).
4. That many options for reductions in flooding in the lower watershed are also consistent with the preservation or improvement of habitat, species numbers, and species diversity in the whole watershed. For example, planting and managing riparian vegetation to improve riparian connectivity and structure will reduce flooding in the lower watershed by slowing down the flood wave and increasing groundwater recharge. It will also improve habitat quality for fish, birds and invertebrates by decreasing water temperature, increasing in-stream habitat diversity, increasing carbon supply to the streams, and decreasing bank erosion. This intern will improve the environment for the people that live in and visit the watershed by providing a tranquil intact connection to the environment that can be enjoyed now and by future generations.
5. That sites of importance be preserved for community enjoyment. These include, historical locations such as old building, bridges, schools, missions, and churches. Recreation areas such as walking trails, fishing and hunting areas need to be preserved. Sites of importance include, archeological locations, spiritual locations such as middens, waterfalls, and mountaintops, and environmental locations of importance such as rare habitats, sensitive species, and species rich areas such as freshwater wetlands, Baylands, and riparian areas.

Sonoma Creek watershed is rich in a wide variety of data. However, there lacks a fundamental scientific understanding of rainfall - runoff processes, and the interaction of hydrology and people with the geomorphological landscape, the habitat needs of valued sensitive species, and the types and amounts of habitat, land and water uses that are sustainable for the long term. There has been a range of biological data gathered in the watershed and Baylands including vegetation coverage, riparian vegetation, fresh and saltwater fisheries, invasive species, bird life, and there is ongoing research and data collection mostly in relation to the interaction of endangered species with their habitat. This work (being carried out by or in collaboration with Sonoma Ecology Center in the upper watershed and by the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the Point Reyes Bird Observatory in the Baylands) is essential to environmental preservation and a sustainable watershed for the future. Any projects initiated in relation to flood reduction or environmental restoration will require careful consideration of the biological community.

A variety of water quality data has been collected in both the watershed and Baylands including some suspended sediment and turbidity data. Available data includes nutrients, physiochemical parameters, suspended sediments, turbidity and some trace chemicals. There is a single analysis of suspended sediment load from the watershed that was determined from data collected in the 1970's. Given the major changes in population and land-use over the last 20 years, these estimates are almost certainly non-representative of contemporary suspended sediment loads. Suspended sediment loads in the Baylands have been collected in the last three years and are thought to be excellent for modeling sediment fluxes in the sloughs of the Sonoma Baylands. However it is still uncertain what the ultimate source of sediment is. Is the sediment deposited in Sonoma Baylands ultimately derived from the central valley or is it dominantly sediment derived from the Sonoma Creek watershed. There are no bed load sediment data available. In short, there are no data sufficient for determining current loads of sediment, nutrients, or trace substances from the watershed and no data available that are suitable for water quality source analysis, although SEC is beginning some modeling using GIS and the Universal Soil Loss Equation. This has strong implications for the 303d Clean Water Act listing that describes the Sonoma Creek watershed as impaired for sediments, nutrients, and pathogens. Clearly water quality data is fundamentally necessary (especially fine and course sediment loads) in relation to design of methods to reduce flooding since sediments are actively being eroded and re-deposited in the channels throughout the watershed and Baylands.

There are a number of hypotheses that describe changes to magnitude and frequency of floods in the lower watershed and Baylands. These can be grouped into:

1. Hydro-modification related to changes in population and land-use, channel roughness, geometry and routing in the watershed above Schellville

2. Changes in channel morphology in the Schellville area through to San Pablo Bay associated with sedimentation in channels and bypass areas and restriction associated with housing and engineering structures

3. Changes in the floodplain geometry associated with people building structures such as bridges, railroads levees, flood levees, houses and other buildings, and associated changes in topography

4. Natural changes resulting from sea level rise or climate change. i.e. flashier storm events

In spite of many hypotheses on the causes of flood damage, there is no consensus on what the definition of flooding really is for the lower watershed area or even if the flooding is natural or human induced. Further, there is no consensus on whether the problem is getting worse or whether there has always been flooding of similar magnitude and frequency. Analysis of data available in the Napa River Watershed shows that flooding in that watershed has worsened over time, but the preliminary analysis does not demonstrate land use as the cause (although climate has not changed significantly). Further work could be done to determine the exact nature of the cause. Many of the hypotheses relate to change in channel and floodplain geomorphology. However, geomorphic data is lacking (stream profiles, cross-sections, substrate character, and bank stability, how channel geomorphology has changed over time in relation to upstream and local influences, and how channel geomorphology in the area around Schellville and downstream to the San Pablo Bay shoreline has influenced flooding). A combination of community consultation, historical landscape ecology, and sound hydrologic and geomorphological analysis is necessary to fill gaps in understanding of the causes of flooding.

Rainfall incident on the Sonoma Creek watershed varies from about 20 inches in the Baylands to 40 inches in the upper reaches in Carriger Creek and 50 inches in the headwaters of Sonoma Creek in the northernmost reaches. Daily rainfall has been collected in the watershed for at least

100 years and there are a number of locations where daily rainfall is still collected. In the 1950's, archival reports show that the watershed at that time had a response of about six hours to storm rainfall. Given the changes in land-use over the past 50 years is seems likely that the response time today will be less that six hours however, runoff data collection ceased in 1982 and rainfall data being collected with a temporal resolution of one day is no use for determining the time of concentrations of such a fast watershed. Sonoma Ecology Center is collecting rainfall and hydrographic data using a network of volunteers. Analysis of this data and comparison to historical data will hopefully help to determine if there has been hydro-modification over time. However, in order to determine water and sediment flows in Schellville area and predict flows under a variety of future scenarios, a network of strategically placed tipping bucket rain gauges and flow-recording stations are needed. Some are already in place throughout the valley with the ADCON system of rainfall data collection, and data may become available through SEC. It is recommended that water, sediment and rainfall be measured on Fowler/Carriger, Sonoma and Nathanson/Schell/Arroyo Seco Creeks over a minimum of two years (10 years would be ideal) to determine rainfall - runoff relationships, response times, and water budgets. If this information were to be coupled with an analysis of historical landscapes, hydrological and geomorphological data, a picture of rate of change over time could be developed and used to predict future effects of population and land-use on flooding in the Schellville and Baylands areas.

The Sonoma Baylands are one of the most important habitat areas of the San Francisco Bay area. In spite of dramatic historical and ongoing land-use changes over the past 150 years they still support a wide variety of species including many endangered and threatened species such as California clapper rail, western sandpipers, marbled godwits, and long-billed dowitchers, northern pintail, salt marsh yellow throat, black rails, San Pablo song sparrow, salt marsh harvest mouse, burrowing owls, white tailed kites, and harbor seals. The Baylands are also home to a number of families who farm the lands for hay, grain production, and grapes and a number of people use the areas for recreation such as hunting, boating and fishing. Any solutions that try to provide for reduction in flooding or environmental restoration in the lower Sonoma Creek watershed will need to take account of this extremely complex mosaic of physical, biological and social human interaction. This is clearly no easy task and will require strong community consultation to help define problems and determine future needs.

The Sonoma Baylands are known to have consisted of a complex and dense system of tidal sloughs, seasonal wetlands and freshwater marshes. These were drained, levees were constructed, and pumps installed to keep salt and floodwaters out of the farmlands. Since that time, sedimentation has filled the sloughs and restricted both the flow of tidal waters and the escape of floodwaters from the watershed upstream. Again, in spite of many hypotheses that relate to changes in hydrology and geomorphology in the Baylands as being the cause of flood damages in the Schellville area and Baylands, there has been no systematic study or modeling to determine what effects if any, the tidal channel hydro-geomorphology is having on the escape of floodwaters. In order to ascertain cause and effect relationships, to determine the effects of changing conditions in the future, and to estimate the effects of potential designs of projects to reduce flooding and enhance environmental aspects of the Baylands, modeling should be conducted. Again, this should be coupled with historical ecology to determine what the system used to be like chemically, physically and biologically, to determine the rate of change over time, and help determine the effects that are likely in the future given foreseeable land-use changes. All modeling and historical ecology should take into account the interaction of the Sonoma Baylands with the rest of the Napa Sonoma Marsh system.

With these facets in mind, the following projects and estimated costs are recommended. The product of such projects will be an Integrated Sonoma Creek Management Plan, which should include recommendations for methods of flood reduction and environmental restoration. This product is likely to take at least fours years to produce and should include consultation and interaction between the community of Sonoma Creek watershed, scientific and engineering groups, and City, County, and San Francisco area environmental managers.

Recommended projects:

1. Community consultation. Anecdotal understanding of the system: where it floods, what damage do floods do? What are the public needs, attitudes, concerns? Who should pay? Sharing technical understanding of watershed functioning with community. $300k.

2. Historical ecology. What were the historical types and distributions of flora and fauna in the watershed and Baylands? When were there floods and how big were they? Has flooding gotten worse over time? Was the flooding as bad before the drainage of the Baylands and the building of bridges? How did hydrologic and other ecological processes create various habitats and interact with flora and fauna? Has the water quality changed over time in the watershed and Baylands? Has the groundwater supply changed over time? $300k.

3. GIS mapping and surveys. Refinements and additions to SEC's GIS database will provide high quality spatial information for watershed and Baylands modeling. GIS data should include coverage's of both historic and contemporary land uses, vegetation types, soil/geologic formations, topographic data, rainfall "surfaces," wildlife habitats, sensitive species distributions and habitat requirements, water diversions/extractions, water quality data, and human population distributions. In the case of rapidly changing land use types (such as areas of vineyards) this information should be mapped with higher temporal frequency and include the previous years distributions where possible. The GIS database should be adapted or designed to provide a tool for evaluating various scenarios of future conditions and monitoring changing conditions with adaptive management. $300k.

4. Hydrological and sediment loads evaluation of the Sonoma Creek watershed. Construct in-stream flow gauge and perform maintenance to measure watershed stream response to rainfall. Perform rainfall data collection, both short- and long-term with small and large collection return intervals in sub-watersheds to evaluate runoff response among watersheds and with respect to various land uses. Evaluate floodplain condition and routing patterns. Install continuous turbidity gauges, monitor total suspended solids (TSS), and reduce and manage data to evaluate how much sediment is moving in main-stem Sonoma Creek and major tributaries during storms. Model flows, evaluate restoration alternatives, including the sediment yield characteristics of sub-watersheds, to gain understanding of sediment production over time and given future land-use changes. Extend Annadel sediment yield analysis to entire watershed to understand soil type and soil moisture retention characteristics throughout the basin affect flooding in the lower watershed. Compile existing soil boring and groundwater monitoring information, construct soil moisture retention curves,

to evaluate soil type and soil moisture retention characteristics throughout the basin. Which upper watershed projects will help to reduce total and peak flows in the Schellville? $350k.

5. Geomorphic analysis of the Schellville area (including lower Nathanson Creek, Sonoma Creek and lower Fowler Creeks). What effect does the geomorphic character in the Schellville areas have on flooding. Has it changed over time and what will it be like in the future given land-use changes? Which upper watershed land management schemes will help to reduce seasonal and total sediment delivery to the Schellville streambed? Evaluate sediment movement to gain understanding of which scenarios cause the greatest change in cross sections of Sonoma Creek (and cross sections of lower Nathanson and lower Fowler, potentially affecting flooding. $300K.

6. Sediment source analysis. Where is the sediment in the Sonoma Marsh coming from? What is the source gradient and how will that affect restoration projects? Has the source of sediment changed over time since the 1850's? For sediment derived in the upper watershed, what hill-slopes are most susceptible to erosion? Which sub-watersheds have the highest sediment yield and restoration potential? During floods what proportion of the sediment derived from the watershed is deposited in the Baylands and where is it deposited (channels, floodplain, wetlands etc)? What is the rate of accretion of sediments in different parts of the system and how will that affect wetlands recovery and flood magnitude in the future? $400k

7. Baylands modeling. Under different design scenarios for flood reduction, what will the new flood heights be in relation to levees currently maintained by farmers in the Baylands? What effects will each scenario have on flood relief in Schellville and other areas of the Baylands? What are the (more effective) alternatives to levees? $250k

Introduction and acknowledgements

San Francisco Estuary Institute was commissioned by the San Francisco district of the US Army Corps of Engineers through Karen Rippey to write a report that summarizes available data in the Sonoma Creek watershed and to make recommendations for future projects by determination of gaps in existing knowledge. SFEI invited the Sonoma Ecology Center (SEC) to collaborate during the writing of this report. Their decision to accept the contract and enthusiasm in providing information is greatly acknowledged. Previously there have also been a number of meetings between Karen Rippey, Paul Sheffer, and lower-watershed landowners, between Karen Rippey and the Sonoma Ecology Center and between Karen Rippey, Lester McKee, and lower-watershed landowners. This current report represents a continuation of all of those efforts.

A Technical Advisory Meeting held at Atwood Ranch in Sonoma Creek watershed on 30th August 2000 was a very informative workshop. This meeting included three members of the North Bay Agricultural Alliance and their participation is greatly acknowledged and was very valuable. Their input at that meeting helped to create five new hypotheses for the causes of flooding in the Schellville and lower Baylands areas of Sonoma Creek watershed and also helped to create the preliminary list of public concerns found in this document. We wish to acknowledge and thank all the people and organizations in the following list of attendees of the August 30th meeting:

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Objectives for this Document

Objective 1:

To determine the range and existence of relevant data for possible future projects (habitat restoration, flood management, pollution abatement) that may address issues of community and governmental concern in the lower Sonoma Creek watershed such as flooding in the watershed (particularly near Schellville and further down stream), habitat quality and connectedness, species decline, invasive species, and restoration of Baylands. Many types of data were considered including data collected using:

1. Government and science institutions
2. Community groups and non-profit organizations
3. Anecdotal evidence derived from contemporary and historic documents and observations.

Objective 2.

To discuss the definition of flooding. Flooding is defined in hydrology as the flood stage at which water escapes the natural channel banks/levees or constructed levee system and flows onto the floodplain. This may not be a suitable definition when human properties and lives are involved. An analysis of the human interaction with floodwaters will be necessary to better define what the definition of flooding is in the Sonoma Creek watershed and Baylands. Factors such as isolation, danger, erosion of land, damage to property, or transportation of garbage may be equally or more important that the magnitude and frequency of floods.

Objective 3:

To determine a set of plausible hypotheses that could describe the causes of flooding in the lower Sonoma Creek watershed especially in the area adjacent to and downstream of Schellville.

Objective 4:

To review the history of mitigation options that have been considered in order to alleviate the negative effects of flooding in the lower Sonoma Creek watershed

Objective 5:

To review the contemporary written and verbal objectives in relation to flood hazard reduction and environmental and recreational restoration in the Sonoma Creek watershed and Baylands

Objective 6:

To discuss data gaps and review facets necessary for the greatest possible success of any future restoration projects in the Sonoma Creek watershed and Baylands

Objective 7:

To recommend a study structure and projects in the form of integrated projects that will lead to the best possible alternatives for environmental management and restoration in the Sonoma Creek study area. This will include an estimated budget for each project and will have as its guiding philosophies ALL **of the principals** described in the section of the report titled "Guiding Principles for successful flood control and restoration"

A brief history of Sonoma Creek - relationships of people to the landscape

During the process of preparing this report, a brief time line was developed that includes a variety of historical information gained from reviewing mainly secondary literature sources (which are potentially fraught with errors in interpretation). Only primary literature, personal accounts, maps, and other historical manuscripts can accurately represent a particular event in space and time. Even then, primary sources may be "influenced" by their original purpose, political climate, personal experience, interpretation, or bias.

There are several very good texts already written on the history of Sonoma and its people (Alexander 1986; Nardo-Morgan 1997; Emanuals and Emanuals 1998; Wilson 1999). These texts help to demonstrate that it takes a professional of considerable experience to determine the accurate history of an area such as the Sonoma Creek watershed. The following time line (Table 1) should illustrate the gross history of human occupation and environmental change that took place in the Sonoma Creek watershed.

The Sonoma Valley is rich in archaeological sites and is considered one of the richest archaeological areas in California. Coastal Miwok Indians on the west and the Wintum on the east influenced the valley. They are said to have arrived at least 10,000 years before present (Nardo-Morgan 1997), and there is evidence of their establishment no less than 6,000 BP (SSCRCD 1997). There is an Indian archaeological site, comprised of shell middens, on the east bank of Sonoma Creek upstream from the state Hwy 121 Bridge (USACE 1972) that is believed to have given the town of Schellville its name (USACE, 1972). On the other hand, DFG (1977) suggest that the town's name was derived from a local landowner named F.A. Schell. This is an example of the difficulty associated with historical research and shows how it is very necessary to go to primary accounts and cross-reference many sources before one can be certain of a particular event in space and time.

Many of the numerous historical sites of interest in the Sonoma Creek watershed, are in the area downstream of Schellville. For example, the Embarcadero landing near Schellville is one of many historic landing sites where people and produce of the prospering 19th century county embarked or unloaded to and from San Francisco. Other landing sites included Essex, Norfolk (Valley Road), Poppes, Stofen, and St. Louis (all predating the 1880's) (Emanuals and Emanuals 1998). Wingo Railway Bridge (dated 1879) is another site of potential preservation importance (Emanuals and Emanuals 1998). Several adobe buildings constructed in the period of 1825-1850 stand in the Sonoma area, including church buildings and homes constructed by the Vallejo brothers (USACE 1972).

Table 1. A timeline of events pertaining to the human relationship to the Sonoma Creek watershed environment.

Date	Reference	Page	Event	Notes
>6,000 BP	2	9	Miwok Indians were established in the Sonoma Valley	
1823	2	9	The last and northern most mission in California was built establishing Sonoma	
1833	2	9	Padre Jose planted the first grapes at the mission for the table and for communion wine	
1834	2	9	General Vallajo took over the mission	
1844	1	11	"General Vallejo's brother Salvador had employed the mission Indians to extract earth from the plaza to make adobe bricks."	
1847	1	59-61 67	Earliest navigation of Sonoma Ck. using flat bottom Scows (37 Foot Sitka=Russian Paddle wheel)) "schow schooner is filled with 250-300 lb. Five wire bales." Mariese (Mary S.) is the first sailing sloop	
1847	1	61	"The embarcadero landing just three miles south of town" [St. Louis or San Luis]	
1849-51	2	9	Haraszthy planted 165 varieties of grapes in his Buena Vista vineyard	
1850	1	42	Dairying was occurring in the lower Sonoma	
1850	1	1	"For much of the 1850's Sonoma residents sloshed through the muddy mire of the town's streets in winter, and in summer they stepped over the crusty, dry pots and potholes created by horses and wagon wheels…dusty streets."	
1851	1	62	"With the exception of the owners of three houses, the population of San Luis was a particularly floating one, being represented for the most part by crews of the fishing smacks, of which there were at times a great number in port."	Frank Marry
1851	1	34	"Charles Lubeck bought 31 acres on lower Broadway."	
1852	1	34	"[Lubeck] purchased 51 acres on the east side of Broadway, adjacent to the first property. A fruit orchard was planted on the second [this purchase] property. Sonoma was a busy place then."	Sonoma County Records, Book of Deeds, "E", page 101, 143, 151
1852	1	35	"Lubeck bought 192.75 acres of good farm land from Thomas O. Larkin to the east but near the 82 acres he bought in 1851."	Sonoma County Records, Book of Deeds, "E", page 5.
1850-71	1	42	"Sonoma Creek, the old swimming hole, was a great place for all ages to enjoy. At one time several boys put in most of the their spare hours building a boat so that they could fish up and down the creek."[seems to be near to where the boys lived in Locust Grove]="located three miles from town [Sonoma] on an often dusty or muddy road."	
1850-60's	1	68	"He [the captain of a hay schooner loaded 14 bales high] would wait for the outgoing tide to ebb before setting out on the return to Sonoma Creek [from Meiggs wharf in China Basin-with load of lumber]. Then he would set sail on the incoming tide to boost him Northward so that he could pass over the bar at Sonoma Creek at high water. [There was a bar at the mouth of Sonoma Ck. which could only be crossed at high water of an incoming tide]	

Date	Reference	Page	Event	Notes
1850's	1	42-43	. "One neighbor [of Locust Grove School] who tilled the land as needed was Julius Poppe…He came to Sonoma in 1850. He had bought 1,500 acres of land, some of it marsh, from Mariano Vallejo, and succeeded in dairying." [planted two rows of locust trees still on school driveway.]	
1854	1	10	County seat moves from Sonoma to Santa Rosa. -Sonoma feels "deserted" "The plaza presented a forlorn appearance, treeless, and unkempt. Untethered cows and horses decorated the dirt streets with paths of manure droppings. Buzzing flies and stench. Here and there, an untied cow grazed, dogs lay scratching fleas, and chickens clucked and crowed. An ugly ditch crossed the square, and a cannon wheel lay over it to serve as a foot bridge."	Richard Boss, Nautical Research Journal, National Maritime Museum, 1984, p. 113
1860's	1	69-72	Granite and Basalt was quarried (from Stockton Hill east of 1st St. West) and shipped to San Francisco for basalt paving stones and building blocks. "San Francisco Embarcadero, originally on east street, had a seawall made with [rock]."Sonoma still abounds in Basalt." Produce included lumber, grain, hay, wine, meat, game, pumpkins, beets, turnips, onions, peas, peaches, cheese, and firewood for "wood and coal wharf in San Francisco."	
1862	1	62	"Numerous warehouses lined the banks of the creek opposite the town [St. Louis][Stofen brothers, "Peter and JJ. came to Sonoma in 1862 and bought some of the best farmland when they acquired almost 200 acres along the east side of Sonoma Creek running south from St. Louis. Stofen landing was the first below the Embarcadero, The brothers built a large warehouse.."	Louis Green, "Sailing Vessels," in Saga of Sonoma, Sonoma: The Sonoma Historical Society, 1976, p.7-8
1862	1	62	Another passenger boat "Princess" was started in response to increasing population	
1862	1	64	Farm land ran along the east side of Sonoma Ck. south from St. Louis	
1860's?	1	65	"The reef points were used for raising the boom over the hay load which was five of seven tiers high. The reef points also made it possible to raise the booms so that they would clear the levees and brush along the banks in the delta country."	Karl Kortum, "Notes on the Scows", National Maritime Museum. Where is the delta country-the delta or the Sonoma marsh?
1862	1	71	In response to growing demand the 53' J.J. Stofen beam 21', draft 4.5' 18 tons displacement and the 36' "Gazelle" draft 4.2' were built	
1868	5	26	Sonoma Valley Prismodial Railway was built, and a combined warehouse, passenger depot, and agent's quarters stood beside the wharf at the end of the track at the steamer landing on Sonoma Creek, 3.5 miles south of Schellville (named after the nearby landowner F.A. Schell (The landing was later named Wingo). The last run of the Prismodial Railway was 1887.	
1878	1	82	Sloop gazelle carries "large quantities of lumber…" on her return from San Francisco.	Sonoma Tribune, Sept. 21,
1880	1	41 52	Locust Grove School-Lubeck lands has a producing orchard of apples, peaches and pears, with chickens and hogs. It is a "working farm with a hayloft, horses, cows, geese, chickens, rabbits, cats and dogs. There were berry patches, swarming bees, birds nest, squirrels, frogs, snakes, a creek for swimming and fishing, and trees for climbing and swinging."	

Date	Reference	Page	Event	Notes
1882	6	21	Local landowners reclaimed about 3,000 acres of Marshland lying between state highway 37 and San Pablo Bay by construction of levees to hold back tidal waters	
Late 1880's	1	74, 76	Many landing on Sonoma Ck. 1st landing Essex, 2nd landing: Norfolk (Valley Road)"the Sonoma Valley Railroad referred to this location as Wingo, and a bridge crossed the creek at this point." 3rd landing: Poppes, 4th landing: Stofen, 5th landing: Sonoma Embarcadero, 6th landing: St. Louis	
Late 1880's	1	74	"Asphalt, the sludge in an oil refinery, wasn't available in Northern California until the first refinery began operation at Alameda Point in the late 1880's." [Supplied first to San Francisco]	George Emmanuels, A mid-California Illustrated History, Walnut Creek, CA, 1995
Late 1880's to early 1900's	6	21	A navigatible channel was maintained along the course of Sonoma Creek downstream from Schellville	
1874 - 1923	1	78	The "Sonoma" was lengthened after she was purchased by the California Transportation Co. from 109' drawing 5' of water to 135' increasing her displacement to 250 tons	
1870's	1	78	"When the tide flowed on the incoming or ebb, the current pushed the water up to six miles per hour past the San Francisco waterfront piers."	
1878	1	82	Produce out of Sonoma included table grapes	
1878	2	9	A fish hatchery was constructed in Glen Ellen for the Lenni Fish Propagating Company	
1879	1	82	Sonoma Valley Railway began operating. There was a lifting bridge across the creek at Wingo	
1880's	1	82, 86	Pacific Reclamation Co. was founded. Sonoma Ck. was widened and deepened by dredging, East side Swamp was channeled and levee's built around "what became six islands". Land drained. Fields were ploughed by Producers Hay Co "for planting oats for hay." Large warehouses constructed.	
1883	2	9, 10	30,000 steelhead eggs were shipped to New Zealand to bolter sport fishing	
1891	1	48	"A large force of men is now at work extending the plaza over the former site of the Sonoma Valley Railroad buildings [terminal site of RR], and the ground is being plowed up to admit the planting of shade trees at the very earliest possible date. Sonoma has a right to feel proud of her plaza. It was laid out by General Vallejo himself over fifty years ago. Of late years, it has been much improved. Trees have been planted, walks repaired."	Shellville Ray, Feb. 18
1891	1	48	"..the railroad had its station, round house, bunkers of wood for fuel…[they often burned green wood p. 45] [Rail line ran to Schellville.]	[Shellville Ray,?
1892-1920's	5	27	Levees were build around Skaggs island, to withhold slough waters	

Date	Reference	Page	Event	Notes
1893	1	91	Gasoline powered scows began. Reginia S. was 68' long and could carry as much hay as five sailing scow schooners	
1900	1	95	Estimated 300 scows in operation, "The wind churned the shallow waters as we approached San Pablo Bay."	Captain Milson in "towed his mate for 9 miles", Petaluma Argus, Sept. 7, 1900
1906	1		Great earthquake of 1906, April 18, killed 50 people in Santa Rosa.	
1906	1	93	The gasoline powered launch "Sonoma Valley drew 4.7' of water, 54 feet long, beam 18'6' as she came up the Schell Slough	
1914	1	97	Rubber tires on truck	
1915	1	95-96	The usefulness of the scows had waned.	
1921	1	85	Wingo Bridge replaced by the present bridge. Wingo station "busy place with hunters in duck season."	
1921	5	26	The steel Bascule Lift Bridge was built just below the old wooden swing bridge	
1927	6	21	A drainage system, consisting of ditches and pumping plants was constructed in the Baylands	
1939	6	11	A report submitted by the army Corps of Engineers recommended drainage ditch construction and channel clearing as options for flood protection on Sonoma Creek not be authorized	
1941	5	27	The Navy purchased part of Skaggs Island	
1946	6	12	The County of Sonoma prepared a report entitles "Flood control report for the Lower Sonoma Valley". This report evaluated flood damages and recommended channel improvements south of Schellville	
1956	4	1	The district Engineer find that a serious flood, drainage, soil and water conservation problem exists in the Sonoma Creek Basin area	
1956	6	21	A public hearing is held in Sonoma in regard to channel improvements and flooding with 100 people in attendance	
1959	6	22	Local interests attempt to alleviate the flood problem on Tubbs Island by improving the outlet channel and adjacent levees from Tolay Creek through the East Branch Slough to Sonoma Creek	
1959	6	12	The Soil Conservation Service (USDA) prepared a report under the watershed protection and flood prevention act that determined that "no feasible project can be developed within the scope of public law 566 at this time"	
1965	6	9	The District Engineer recommends the United States adopt a project in the Sonoma Creek basin consisting of channel improvements and recreation facilities	
1965	6	21	The major proportion of the once navigatible channel is entirely filled with sediment	

[1] Emanuals and Emanuals, 1998
[2] SSCRCD 1997
[3] Anon. 1957
[4] Corps of Engineers, U.S. Army (1956)
[5] CDFG 1977A
[6] Anon. 1965

Section 2.
Sonoma Creek Watershed Characteristics

Introduction

Geology, soil characteristics, watershed hydrology, vegetation types, and land use all interact to influence sediment transport, erosion/sedimentation, flooding, impairment of natural watershed functions and biodiversity, and resulting restoration potential. The Sonoma Creek watershed covers an area of approximately 170 square miles. The watershed is roughly rectangular shape, stretching about 25 miles from north to south and about 10 miles east to west at its widest point (Figure 1). The Sonoma Creek watershed is bounded in the west by the Petaluma River watershed and in the east by the Napa River watershed. To the north lies the Russian River Watershed (Santa Rosa Creek), and in the south, Sonoma Creek flows to San Pablo Bay via a number "circular" sloughs that have, over the last 150 years, been highly modified by dredging, levees, and re-alignment. As shown later in this report, the true boundary of the lower Sonoma Creek watershed is somewhat obscured by complex water circulation patterns associated with the Napa / Sonoma Marsh Complex, and therefore all observations, interpretations and options for possible future restoration will need to take into account the entire Marsh complex as a single entity.

Geology

Geological information can be gained from the regional geological map series, Santa Rosa Quadrangle (California Division of Mines and Geology 1982), a report on groundwater (Department of Water Resources 1975), and California Division of Mines and Geology 1980. The Sonoma Ecology Center (SEC) has GIS coverage's of bedrock geology in various stages of development for the watershed. USGS maps of bedrock geology are available at 1:12,000 scales, but only a few of these maps are currently digitized. However, USGS is expected to have these digital files available by the end of 2000.

The geology of the Sonoma Valley is dominated by Sonoma Volcanics of Pliocene age. These are inter-bedded flows of locally welded tuff breccias, welded tuff, agglomerate, and andesitic and basaltic flow rocks. They include some minor beds of volcanic sediments.

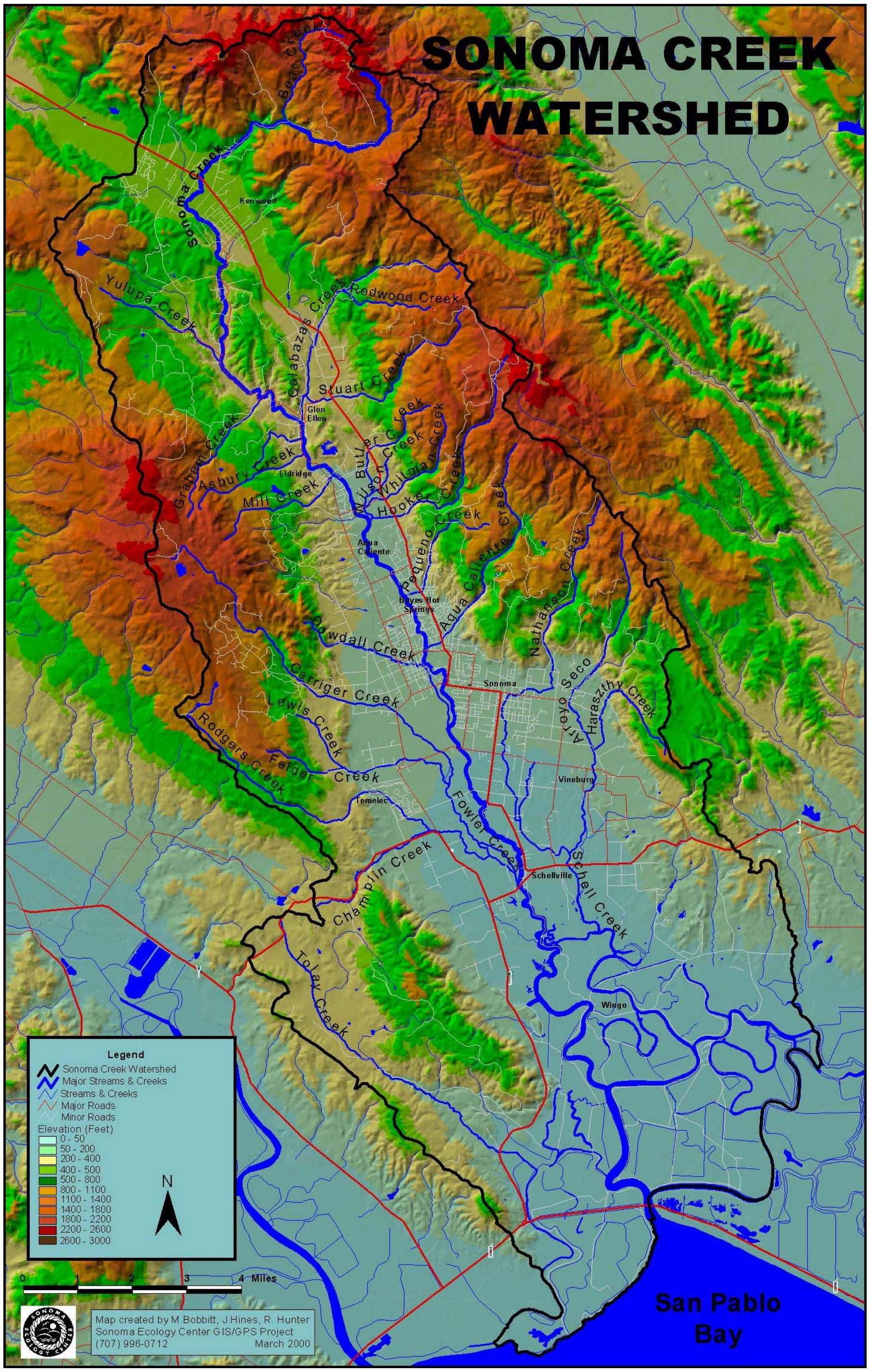


Figure 1. Sonoma Creek Watershed including the Baylands. The map suggests three main sub-watersheds. 1. Sonoma Creek, 2. Fowler Creek which includes most the creeks west of Schellville and the City of Sonoma, and Nathanson Creek and Creeks to the east of Schellville and the City of Sonoma. All three of these sub-watershed areas collect at or near Schellville. (Supplied by Sonoma Ecology Center).

There are outcrops of Petaluma Formation (Pliocene brackish water deposits of clay, shale sandstone, nodular limestone, and conglomerate). The valley flat areas have a range of deposits of Pleistocene to Holocene age including the Glen Ellen Formation (poorly sorted silty clay, clayey gravel, sand, and gravel), Pleistocene alluvium, Holocene alluvial fans on the valley edges, inter-bedded clay silt sand and gravel on the valley floors, and stream sand and gravel deposits along the streamlines. Holocene unconsolidated deposits of Bay mud, stringers of fine sand, and zones of peat and organic clays underlie the lower Sonoma Marshlands. “Older Bay mud” covers the bedrock base and was probably deposited during an inter-glacial period of the Ice Age when glacial melt raised sea level and filled the San Francisco Bay depression (DFG 1977). Some of the most recent deposition occurred because of the mining period of last century. The sediments underlying the Napa Marsh are described as soft compressible alluvials of silt and clay with peat and local thin sand and gravel deposits (CDFG 1977A).

Several notable faults are aligned roughly southeast – northwest influencing the Sonoma Creek watershed. Rogers Creek Fault passes through the headwaters of the creeks that flow into Sonoma Valley on the southwestern side of the watershed, and Tolay Fault runs down Tolay Creek and enters the Marshlands a few miles west of the entrance to Sonoma Creek. Both of these faults are considered potentially active (California Division of Mines and Geology 1980). Numerous other potentially active faults in Sonoma County as a whole include Burdell Mountain Fault, Chianti Fault, Healdsburg Fault, Maacama Fault, and the San Andreas Fault. There are also a few others that are “possibly active” including Black Mountain Fault, Dianna Rock Fault, Tombs Creek Fault, and Mt. Jackson Fault (California Division of Mines and Geology 1980). The incidence of faulting in the Sonoma Creek watershed leads to the potential for earthquake-related processes, such as liquefaction in the Baylands or along saturated river channel sediments, landslides and slope instability (California Division of Mines and Geology 1980).

Soils

Maps of the 1972 Soil Conservation Service survey of soil types have been digitized at 1:20,000 scale for much of the valley bottom and vineyard areas of the watershed by SEC. The hill-slopes are largely unmapped. The state’s Farmland Mapping and Monitoring Program (FMMP) have developed a useful dataset for farmland types. It includes information about the farmland importance, type, soils, and other factors. The USDA has not digitized soils maps for Sonoma County at this time but they are actively pursuing funding that will allow completion of digital soils maps for the San Francisco Bay area.

Topography

Upper watershed

Sonoma Creek flows from its headwaters in the Sugarloaf Ridge State Park. The height of this area is up to 2790 feet. Mountainous ridges bound the valley to the east and west. It has an extensive valley floor, and expands out onto a low-lying tidal floodplain downstream of Schellville. SEC's GIS database contains ground elevations in the form of the digital elevation models (DEM) at 10-meter and 30-meter resolutions. A DEM is used to create topographic contour lines at any interval and degree of slope. SEC is conducting hydrologic modeling using the digital elevation model (DEM) to calculate upslope watershed area, slope length, flow direction, flow accumulation, aspect, etc. DEM's are also useful in delineating sub-watershed boundaries (Figure 2).

Marshlands

Topography of the lower Sonoma Baylands can be gained from the USGS Sears Point Quadrangle (USGS 1951). Although this map is compiled with a 20 feet contour interval, there are spot heights throughout the Marshlands indicating much of the area (e.g. Tubbs Island, Camp 1, Camp 3, Camp 4, Camp 6, and Skaggs Island) are below sea level. Bissell & Karn conducted detailed surveys in 1993 at two scales, 1 inch = 1,000 feet, and 1 inch = 400 feet, for the Department of the Navy (Department of the Navy 1993a,b,c,d,e,f,g). These maps cover the area from Sears Point in the southwest to the junction of Hudeman and Napa Sloughs in the northeast. Areas of up to 3.2 feet below the NGVD29 datum are indicated. To convert this datum to mean lower low water (MLLW) 2.11 feet can be added. Given that the tidal range in the Sonoma Marsh system is about 5.87 feet (MHHW to MLLW) measured at Wingo August to October 1979, this would indicate that the majority of Skaggs Island is at or below mean sea level.

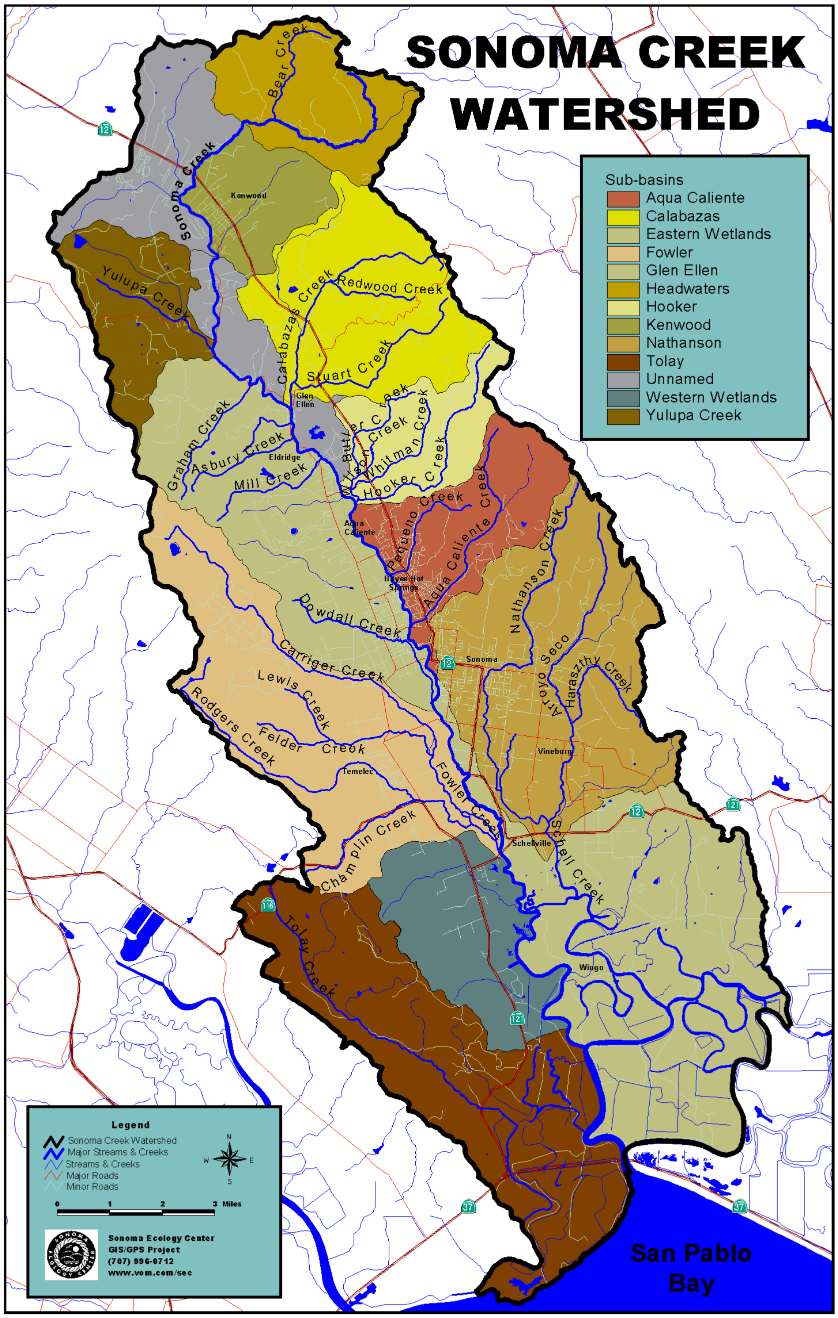


Figure 2. Sub-watershed boundaries in the Sonoma Creek Watershed (Supplied by Sonoma Ecology Center).

Watershed vegetation and land-use

Middle and upper watershed

Historical

Information on population and land-use for Sonoma County as of 1960 including maps that can be viewed in an economic base study prepared by the U.S. Army Engineer District, San Francisco (USACE 1962). At that time, the population of Sonoma County was 24,700 persons, and at that time, it was predicted that the population would grow by the year 2000 to 135,000. Census figures available today from Department of Finance, Demographic Research Unit, http: / / www.dof.ca.gov, show that Sonoma County's population has increased to 440,500 persons (1998 figures). In 1960, agricultural lands covering 67% of the area dominated the landscape of Sonoma. A further 29% were unused, undeveloped, or public reserved lands, and the remaining 4% was residential, commercial or industrial (USACE 1962). Aerial photography is available for Sonoma County from the UCB Earth Sciences and Map Library for the years of 1965 (scale of 1:2,400 and 1:4,800 black and white with stereo overlap), 1968 (scale 1:185,000 back and white), and 1979 (scale of 1:6,000 and 1:12,000 black and white).

Contemporary

The entire set of USGS digital ortho-photo quarter quads (DOQQ) of the Sonoma Creek watershed and adjacent areas have been acquired by SEC. The images were recorded in 1994 at one-meter pixel resolution. SEC also holds a 1999 ortho-photo with one-foot resolution for the area including the City of Sonoma. A full set of 2000 digital ortho-photos will be available from the county of Sonoma in 2001. The database also includes a June 1994 scene of Landsat TM satellite imagery (30-meter cells) for the upper watershed. UCB Earth Sciences and Map Library holds aerial photography (true-color images with stereo overlap) for the Sonoma Creek watershed for the 1999-year at a scale of 1:24,000; call number Air Photo WAC-C-99CA).

SEC is developing a GIS of parcel-level data for the Sonoma County Water Agency. These data will cover the entire Sonoma Creek watershed. Property lines were geo-referenced to USGS Digital Ortho-photography, and parcel polygons were created from these adjusted lot line locations. Each parcel polygon was then attributed with its Assessor's Parcel Number, which can then be used to link the polygons to a wide variety of database fields, including land-use, zoning, ownership, etc. This should be completed by December 2000. This fine-scale data set provides an opportunity to create an index of land-use types, roads, and other sources of sediment production. The project also includes an updated street coverage geo-referenced to USGS Orthophotography and other infrastructure coverage's listed below.

GIS coverage's of roads are available for the entire North Bay region. The attributes include road type, name, and route number. The USGS digital line graph files include railroads as well. Public land survey coverage's can be queried for township, section, and range. SEC has collected and mapped GPS data for many of the publicly accessible trail systems in the watershed. Some of these trail coverage's are associated with trail erosion monitoring projects, such as the one at Annadel State Park. In these cases, the trails data can be queried by various indicators of condition, such as trail width, down-cut depth, proximity to stream, and other factors.

SEC's GIS database includes administrative boundaries for cities, counties, districts, and public lands. The county-owned lands of Napa and Sonoma are attributed with their management unit name, agency, and government level. Sonoma Land Trust, SCAPOSD and GreenInfo Network have supplied SEC with coverage's that show North Bay conservation lands, including easements, state and federal lands, and local parks. These can be queried by owner organization, type of administration, level of protection, and brief description.

Land-use designations in the County of Sonoma General Plan are also found in SEC's GIS (Figure 3). The coverage's can be queried by land-use designation, allowed density, and open space element designations. The data have not been updated since the 1989 draft, but the county is due to release a new version. City land-use designations are also available from the City of Sonoma General Plan. SEC's GIS database includes the state's Natural Diversity Database, but there are very few records of rare, threatened, and endangered species for the watershed. Rare, threatened, and endangered species are notoriously difficult to track and map consistently over large areas, and a watershed dominated by private lands does not facilitate even sampling of species distributions.

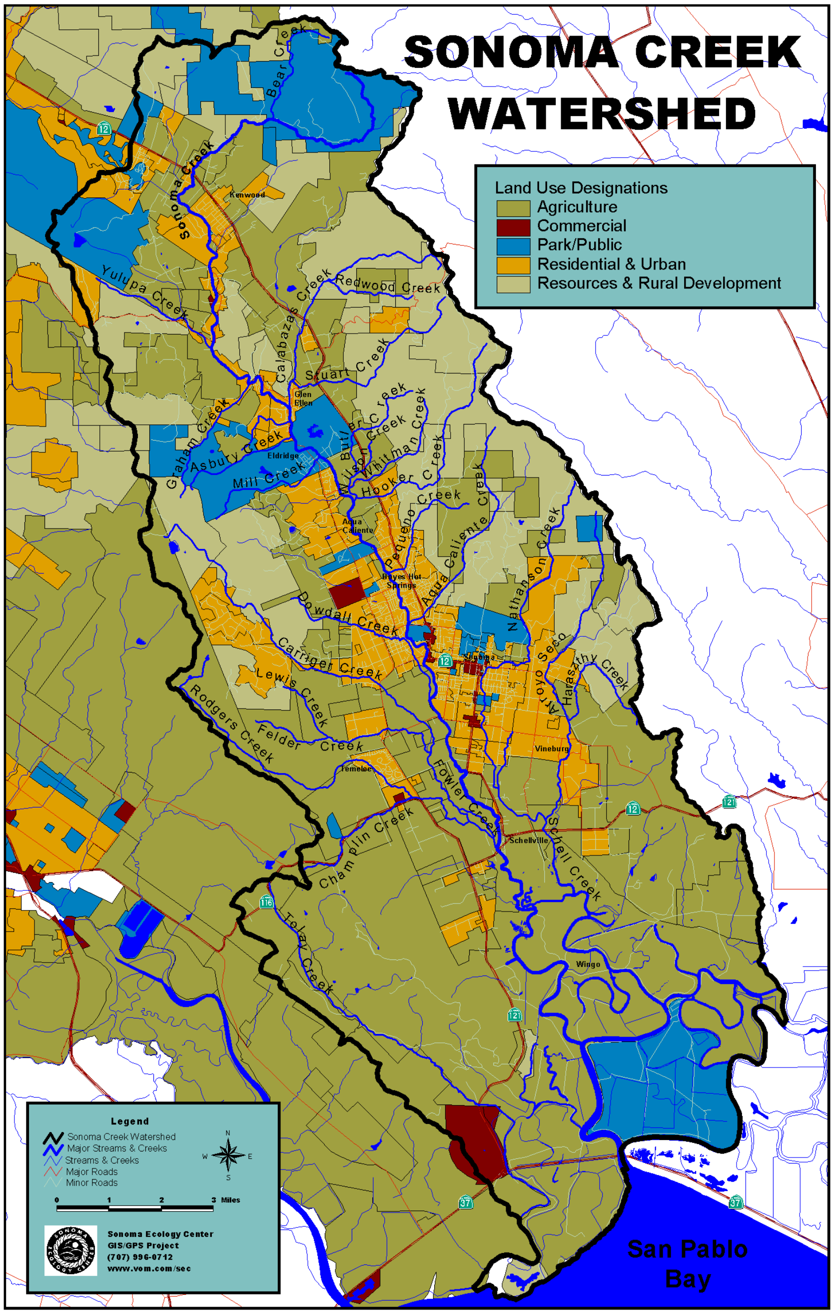


Figure 3. Sonoma Watershed land use designations (Supplied by Sonoma Ecology Center).

SEC also holds the databases 'GAPVEG' and 'Hardwoods' for upland vegetation. GAPVEG consists of polygons attributed with Holland vegetation types and Wildlife Habitat Relationships (WHR). The data set was created for the statewide gap analysis program by UC Santa Barbara in 1998. Good for regional level analysis, the dataset was created from Landsat imagery with a large minimum mapping unit of 100 ha. The hardwoods coverage was created by California Dept. of Forestry also using Landsat imagery; the data are mapped at a finer-scale and depict general vegetation types in 30-meter pixels. However, the satellite interpretation for the Sonoma Creek watershed lacks precision, and a large portion of the watershed is lumped into one category defined as 'other.' SEC's GIS also includes a statewide coverage of broad land cover types derived from Landsat imagery (USGS National Land Cover Mapping program), but this was based on data from the early 1990's and late 1980's. SEC is working towards developing a current field-based vegetation coverage for the entire watershed, but only a few areas are currently available. One piece of SEC's vegetation mapping program is focusing on riparian vegetation mapping using aerial photographs and fieldwork. A tree inventory for the city of Sonoma is available as a GIS point coverage that can be queried by species.

Baylands

Historical

The Habitat Goals Project (Goals Project 1999) and the Bay Area Eco Atlas (©1999 SFEI) describe the past distribution of habitat complexes and slough locations in the lower Sonoma Creek Baylands. Brackish marshes once extended along the major creeks in the North Bay. Under fresher conditions and in the areas further from tidal influence, the brackish marshes graded into seasonal wetlands with associated changes in plant and animal species. Historically, in the 19th century, a bar existed at the mouth of Sonoma Creek that could only be crossed at high tide by Scows. Channel geometry prior to European era modification can also be viewed on historical "T sheets" (U.S. Coast Survey, 1856). These show evidence of the complex and extremely dense nature of the historical tidal channels prior to drainage, dikes, and other modification associated with navigation and agricultural pursuits. This complexity is typical of the northern Baylands with hundreds or thousands of tidal pans scattered between sinuous channels. The pans were smallest and most numerous in saline areas and lager in more brackish areas. Adjacent to the Sonoma Baylands on flatter portions of the region, the tidal marches graded into low-lying moist grasslands with vernal pool complexes on ancient impervious clay soils (Goals Project 1999). Lake Tolay, in the hills between the Sonoma and Petaluma Baylands covered several hundred acres, many times more than the cumulative total area of all other North Bay perennial, non-tidal lakes and ponds. It no longer exists today.

Contemporary

The modern picture is substantially different. In the 1880's, the Pacific Reclamation Co. was founded, and Sonoma Creek was widened and deepened. Baylands began to be channeled and levees built around six islands (Emanuals and Emanuals, 1998). By the 1930's, diking on the North Baylands was essentially complete; the main land-uses being hay making and grazing. The result was almost total land-use change from natural marshlands to high-producing agricultural lands in the Lower Sonoma. In the late 1990's to present, the small portions of the diked Baylands have been converted to vineyards; for example, some areas in the Schellville and northern Skaggs Island areas, and several new commercial real estate ventures are being proposed. There are several managed diked wetlands near the hills of the northern periphery of the Sonoma Baylands and adjacent to highway 37. Tidal marsh is limited to the Bay edge and along the sides of some of the levees. There are some muted tidal lagoons adjacent to highway 37 and Tolay Creek (Goals Project 1999). Maps of habitat types in the Baylands were developed by interpretation of aerial photographs (CDFG 1977b). Maps of the area between Schellville and San Pablo Bay are illustrated along with areas designated for each habitat type.

With the huge reduction in wetland areas in the lower Sonoma Creek watershed, vegetation changed either by active removal or passively through loss of sustainable minimum habitat sizes, changes in salinity regime, or competition by niche species. For example, on the lower Sonoma Creek Baylands today there is no known occurrence of Mason's Lilaeopsis (a brackish channel bank tidal marsh plant) or Soft bird's-beak (an upland edge brackish tidal marsh plant) both of which were probably present.

Riparian vegetation

Riparian vegetation is important for maintaining creek diversity, increasing bank stability, filtering pollutants from the land surfaces, supplying organic carbon, shading and habitat. Dominant native tree species in the riparian areas include California bay, Black Walnut, Maple, Oaks, Alder, California Buckeye, Willow, California box-elder, and Blue Elderberry. Common native under-story plants include California Wild Grape.

SEC has conducted a pilot study for mapping riparian vegetation (draft report available from SEC). This study helped develop methods for characterizing riparian losses. SEC intends to expand the pilot study to include the entire floor of the Valley, and to ensure that results reach citizens, local, and regional governments and agencies. The pilot study includes a 6,600-acre area around the City of Sonoma of approximately 2.5 x 3 miles. Riparian vegetation was evaluated for corridor width, connectedness, and canopy cover, and compared with setbacks as prescribed in Sonoma County's general plan. SEC will identify site-specific effects of land-use and roads on the riparian zone. By integrating this information with the other studies, recommendations will be made for restoration work, new policies, and target outreach in key areas. A much coarser-scale coverage of riparian vegetation data derived from 1994 Landsat TM imagery (30 meter cells) by the California Department of Forestry is also available as a supplement to the Hardwoods coverage.

SEC is currently carrying out a project conducting interviews with long-time residents. One of the topics of the interviews will be anecdotal evidence of historic extent and condition of riparian forests and flood zones.

Invasive Species

Middle and upper watershed

Several riparian invasive plant species have minor to major infestations in various stream reaches. These can negatively affect water chemistry, channel capacity, vulnerability of banks to erosion, recruitment of native riparian species particularly trees, quality and quantity of organic inputs to the stream, water temperature, in-stream habitat diversity, and avian and terrestrial habitat quality.

Major invasive riparian species are Arundo, Vinca (periwinkle), Acacia, tree of heaven, ivy, annual Mediterranean grasses. Himalayan blackberry is a slighter lesser threat; while extensive, it has some habitat value. SEC has been working with volunteers to map most of the *Arundo donax* infestations in the watershed on USGS 7.5 minute quads. These data are being compiled to form an *Arundo* coverage GIS data layer. The data are being used to plan restoration activities related to *Arundo* eradication.

Baylands

The distribution of key and potential invasive species of concern in the Bay area have been prioritized and mapped based on many contributing author surveys (Grossinger et al. 1998). During the development of this document, 12 key species were identified which occupy Bayland habitat locations from saline tidal marsh to the fresh end member of the salinity gradient. Changes the landscape in the lower Sonoma Creek watershed can potentially create habitats not only suitable for native species but also for non-native invasive species. *Lepidium* is a perennial herb that grows on beaches, tidal shores, saline soils and roadsides. It is abundant in North San Pablo Bay in areas adjacent to Sonoma Creek (Petaluma, Tolay Creek's lower reach, and along the tidal shores of the Napa-Sonoma marshlands). *Solsola soda* (Glasswort) is found on mudflats, in open areas, and among pickleweed in salt marshes, on berms, among riprap, and in open areas at or above the high tide mark that are inundated only for short periods or dry for a substantial part of the summer. In North San Pablo Bay *Solsola soda* has been recorded at Pt. Pinole near the Petaluma River and in areas of the Napa-Sonoma marshlands. There are no recorded sites in the North San Pablo Bay marshlands for other key species of concern, which include *Spartina alterniflora, Spartina desiflora, Arundo donax, Spartina anglica*, and *Spartina patens* (Grossinger et al. 1998).

Section 3.

Weather and Climate and Runoff

General description

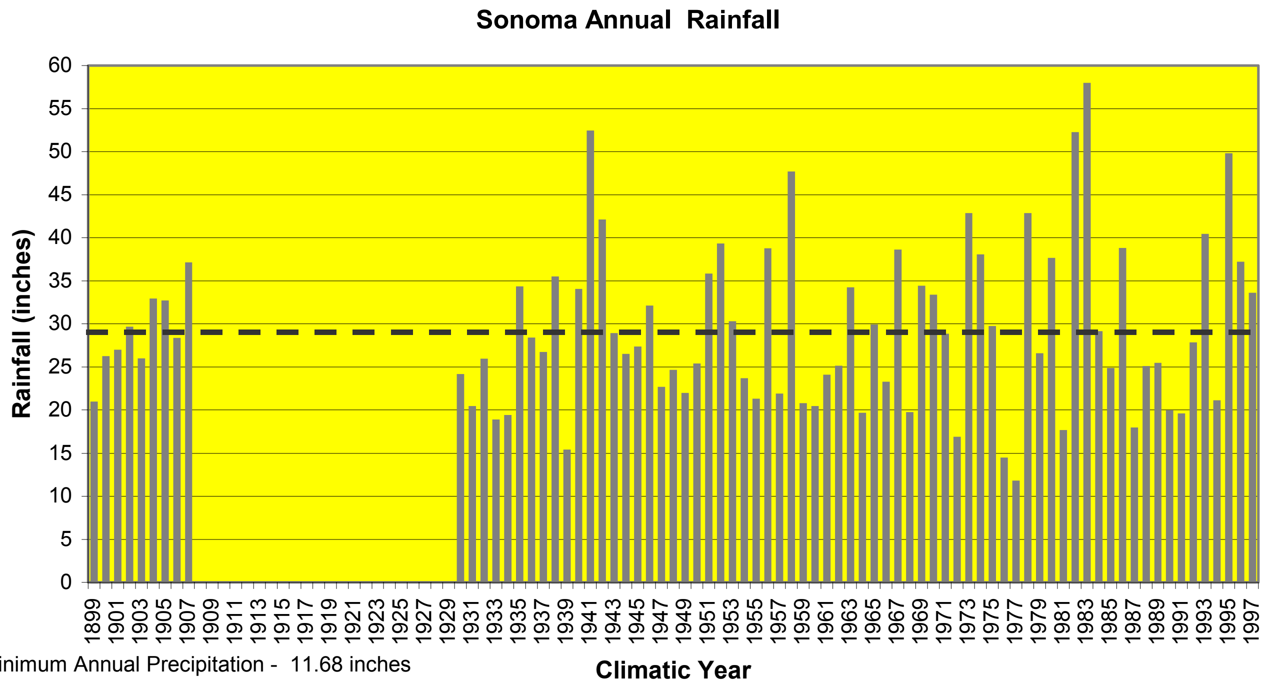
Climate in the Sonoma Creek watershed is Mediterranean (dry summer sub-tropical) typified by dry warm summers and cool wet winters. Temperatures may exceed 100ºF occasionally and lows occasionally reach several degrees below freezing (Sonoma Valley Soil Conservation District, 1965). July is the warmest month with an average daily temperature of 69.0ºF, and January is the coolest months with an average daily temperature of 46.3ºF (Sonoma Valley Soil Conservation District, 1965). Fog is a common occurrence in the Napa / Sonoma Baylands. In summer, fog is formed by warm, moist air cooling and condensing over the cool ocean currents. Westerly winds blow the fog in to San Francisco Bay after it forms. Fogs can also occur in the winter because of condensation of warm moist air at the ground surface. The fog is often drawn outwards across the Baylands to San Pablo Bay (CDFG 1977A).

Rainfall

Rainfall records

Rainfall records are available for the City of Sonoma at General Vallejo's Home on Spain Street (station number 48351) for the period 1899 to 1907 and 1930 to present (Figure 4). The average of this record is 29.2 inches with an inter-annual coefficient of variation (32%). Rainfall records are also available from the Sonoma County Water Agency for varying periods at varying locations. The Sonoma County Water Agency has also developed an isohyet map of rainfall distribution for their jurisdictional area that includes the Sonoma Valley watershed (SCWA 1983). The California Department of Parks and Recreation collects rainfall at several locations in the Sonoma Creek watershed in addition to General Vallejo's Home. Rainfall records are also collected at the water-treatment facility at the Sonoma Developmental Center, the Hanna Boys Center near Agua Caliente, and at the sewage treatment facility on Schell Slough.

Between 1955 and 1981 the totals varied from a minimum of 15 inches (1977) to a maximum of 70 inches (1967) at the water-treatment facility at the Sonoma Developmental Center. Starting in the 1998-1999 rainy season, Stream Stewards, working with SEC, have been collecting rainfall



Minimum Annual Precipitation - 11.68 inches
Maximum Annual Precipitation - 57.83
Mean Annual Precipitation - 29.2 inches
Coefficient of Variation - 32%
Data available for climatic years 1899 - 1907 & 1930 - 1997

Figure 4. Rainfall recorded for the City of Sonoma at General Vallejo Home on Spain Street (station number 48351).

data daily during the rainy season, and more often during storms. Data are currently being analyzed. Stream Stewards will continue to take rainfall data. An automated rain gage was temporarily installed last wet season, and a permanent gage is planned for the 2000 season, which will improve the quality and consistency of the data. An automated monitor installed at the Sonoma Mission Inn Golf Course within the last year is recording evapotranspiration potential.

Drought years and wet years

From an analysis of the station 48351 data, it is immediately evident that the Sonoma Creek watershed is marked by long periods of less than annual average rainfall, the longest of which occurred in the late 1980's. In fact, for the climatic years from 1987 to 1994 inclusive (a period of 8 years) there was only one year (1993) that had greater than average rainfall. A simple tool that climatologists use to determine periodic climatic change is to sum the deviation from the mean accumulatively for the period of record (Figure 5). Climatic years with less than average rainfall record a negative deviation. Conversely, for climatic years with greater than average rainfall, a positive deviation is calculated. When these are summed accumulatively, a negative slope of the graph show continual drought. Conversely, many years in a row with more than average rainfall (positive deviation) will accumulate and form a positive slope. Looking back through the station history, droughts have occurred in the 1930's (9 years with below average rainfall with the exception of 1935 and 1938), and the 1940's (8 years below average rainfall with the exception of 1946), and the 1960's (8 years of below average rainfall with the exception of 1963 and 1965).

In general, it appears that wetter than average periods are not as persistent as droughts. The 1941, 1942, and 1943 years were wetter than average; the 1951, 1952, and 1953 years were wetter than average; the 1973, 1974, and 1975 years were wetter than average; the 1982, and 1983 years were greatly wetter than average and the 1995, 1996, and 1997 years were wetter than average. Of the ten largest peak discharges during the period 1955 to 1981, seven out of ten occurred during climatic years that followed a wetter-than-average year and two more were second peaks during a single month illustrating the effects of antecedent soil wetness on flood generation.

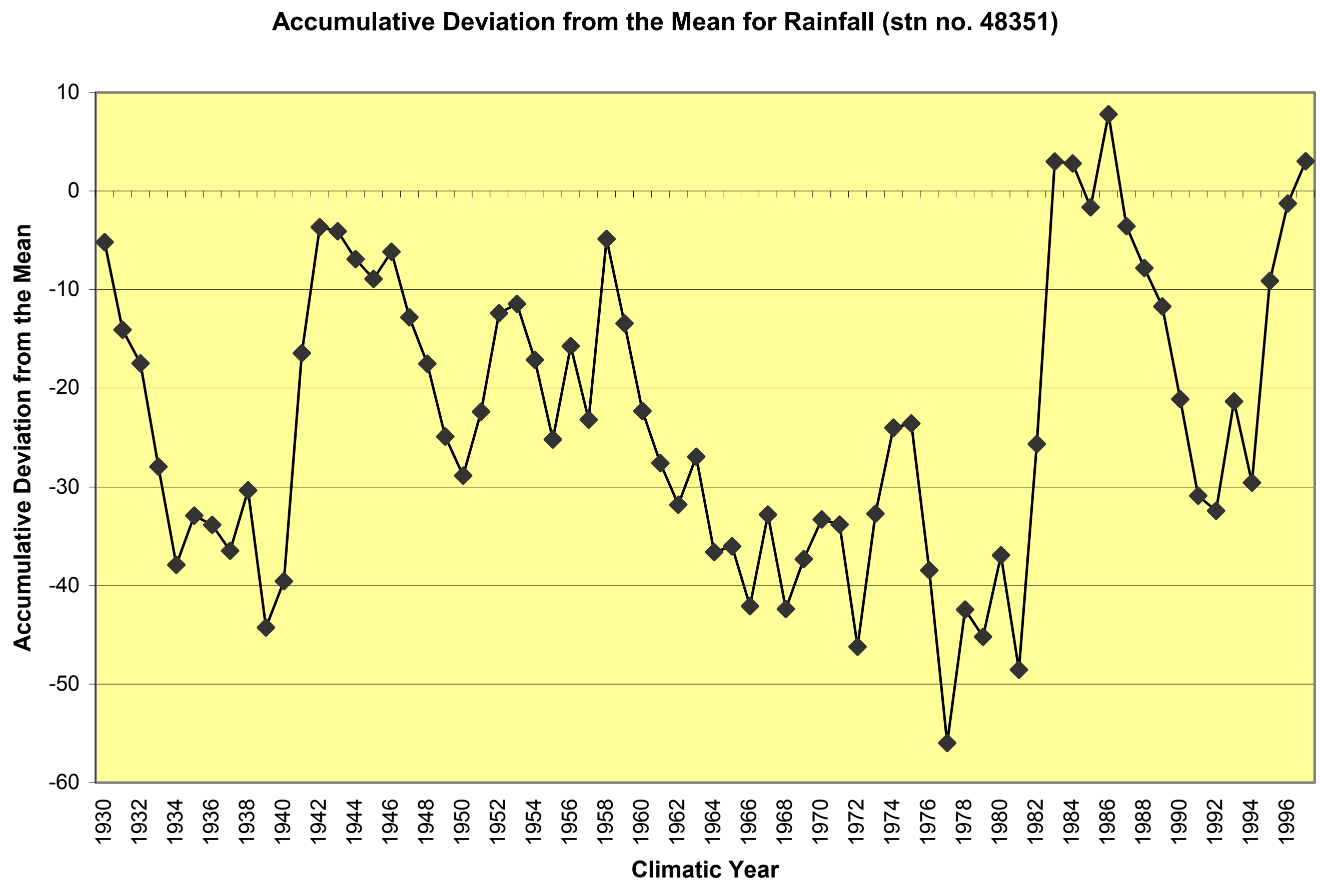


Figure 5. Accumulative deviation from the mean calculated for rainfall in Sonoma (station number 48351).

Monthly Rainfall variation

Monthly data records were used to determine average monthly rainfall (Figure 6). Data for the town of Sonoma indicated that on average, January has the highest rainfall (6.76 inches) and the month of July has the lowest rainfall (0.04 inches). On average, rainfall during the month of January forms 23% of the years total and the wettest 6 months (November to April) comprise 90% of the annual rainfall on average. Comparisons with Petaluma (station 46826), Napa, Santa Rosa, and Saint Helena are provided (Figure 6). The Santa Rosa station (47965) has a very similar rainfall variation to the City of Sonoma location and an annual average of approximately 31 inches. The monthly data record for Sonoma is good, with only eight months with missing daily records during the years on record. With the exception of March 1985 and December 1993, all the months where daily records are missing, the neighboring stations of Petaluma and Napa (station 46074) recorded less than 27 hundreds of an inch. Therefore, extrapolation could be used to generate missing data in these low rainfall months introducing little error (in fact many of these missing months recorded zero rainfall at neighboring stations). Figure 7 illustrates the regression relationship of monthly rainfall collected in the City of Sonoma and the data collected at the Petaluma Fire Station. During months with lower rainfall records, the strength of the correlation decreases indicating localized precipitation rather than regional storms. In the case of the regression between Sonoma and the data collected at the Napa Sate Hospital (Figure 8), the relationship is much less reliable suggesting changing climatic patterns and associated rainfall farther from the Pacific coast.

Frequency, depth and magnitude

An analysis of varying depths of rainfall associated with difference in storm durations and frequencies (Figure 9) shows that, on average, 2.68 inches of rain would fall during a one-day storm with a rainfall intensity that occurs once every two years. The largest daily discharge for the period of available runoff records (1955-1981) occurred on the 21st of January 1967. The largest daily rainfall for this event recorded in the town of Sonoma of 3.3 inches also occurred on the 21st of January 1967. This has an approximate return interval of once in five years. However, after a five-day period, 8.05 inches of rain had fallen with a

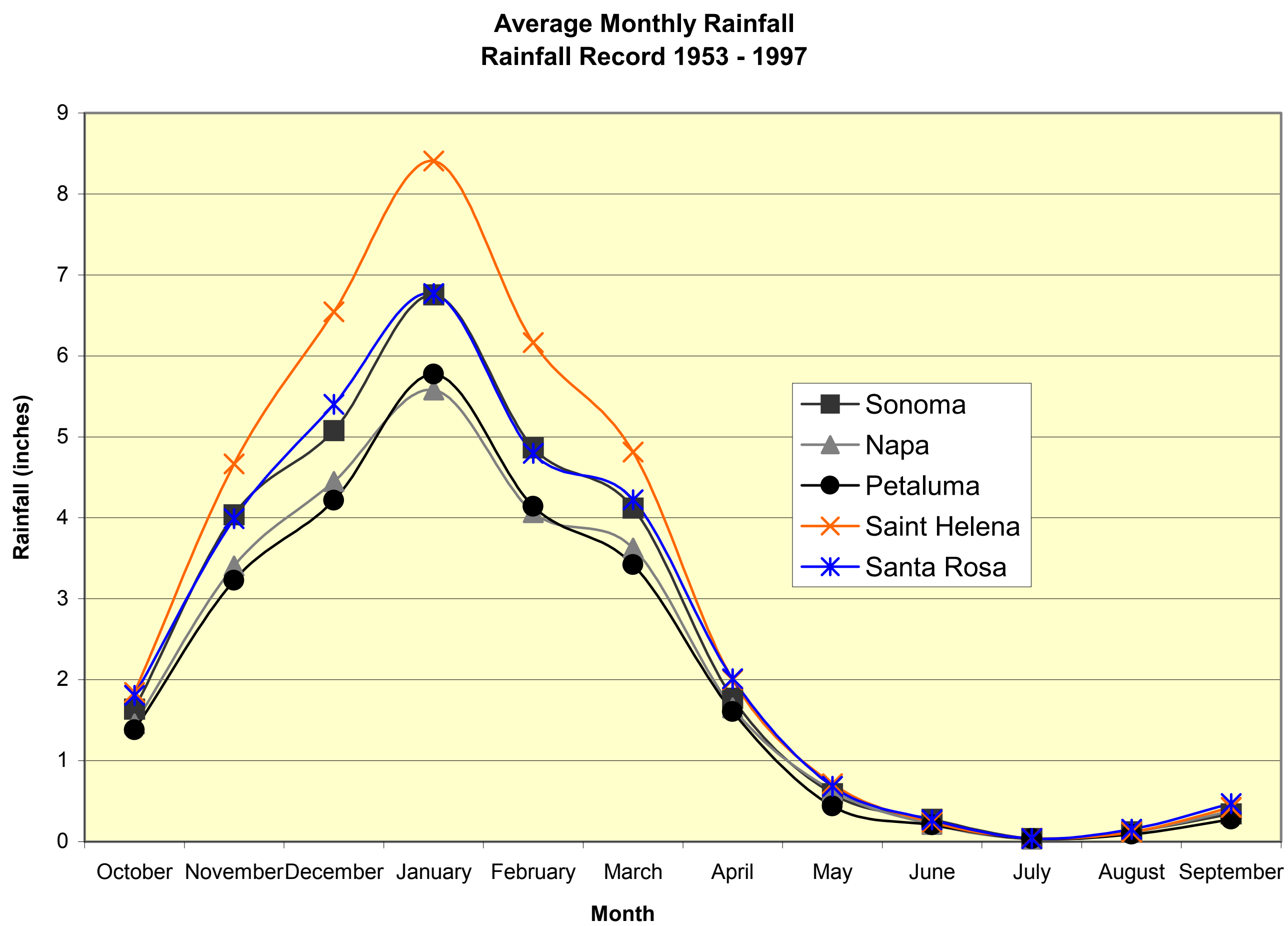


Figure 6. Monthly variation in rainfall for selected location in the North Bay.

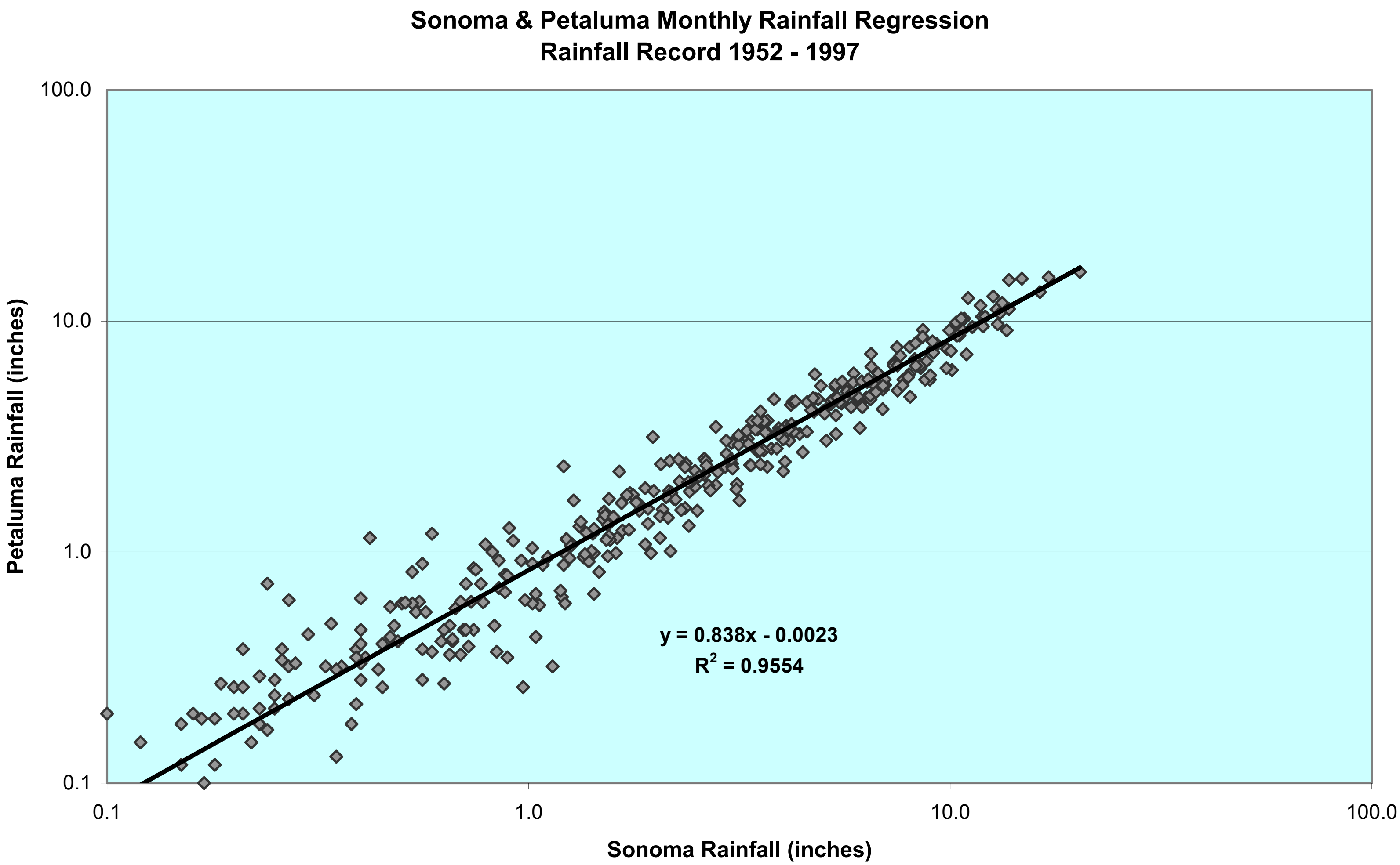


Figure 7. Relationship between rainfall falling at Sonoma and Petaluma Fire Station.

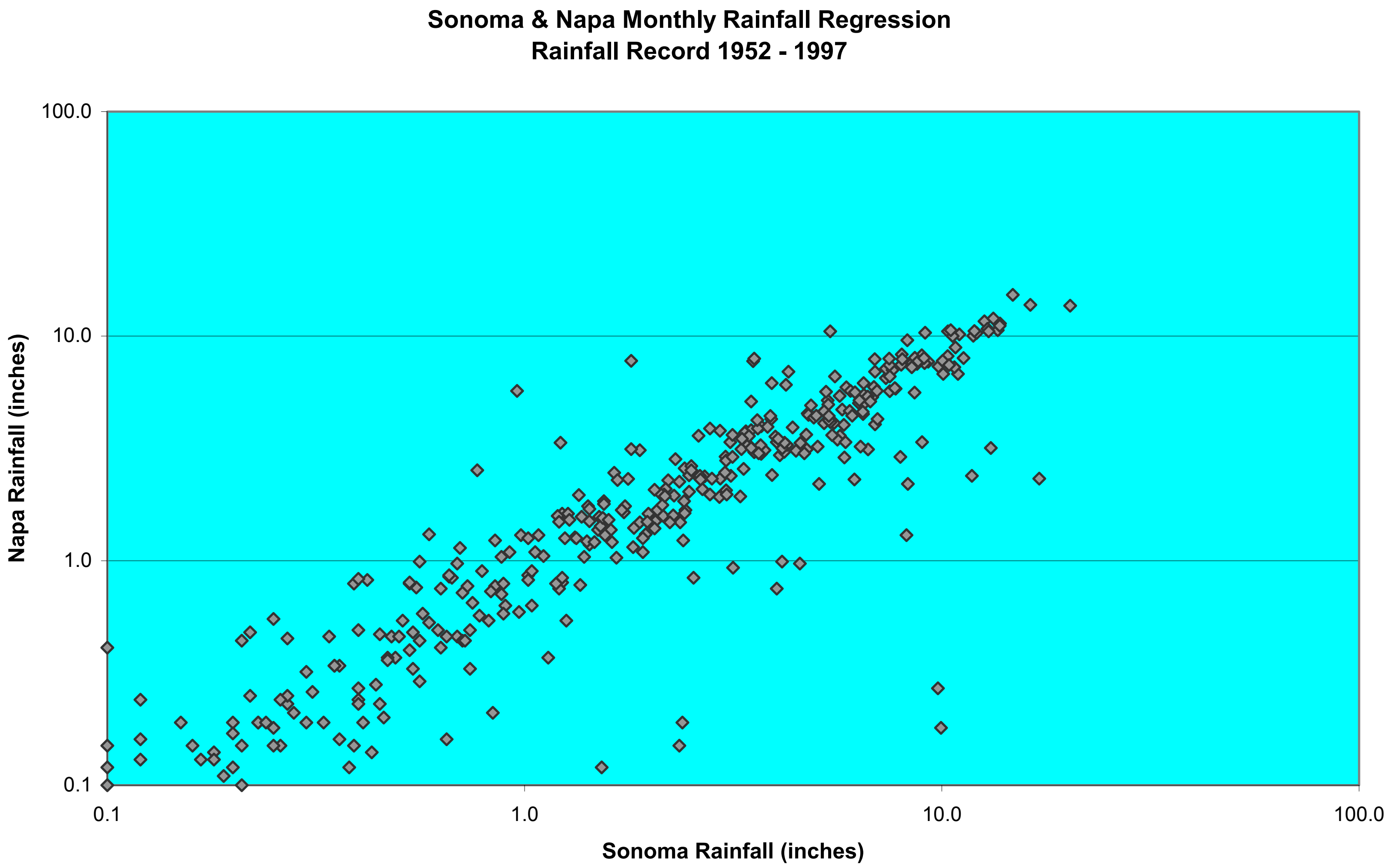


Figure 8. Relationship between rainfall at Sonoma and rainfall at Napa. A poor scatter indicates that storms that occur in one watershed do not always occur with the same intensity in the other watershed.

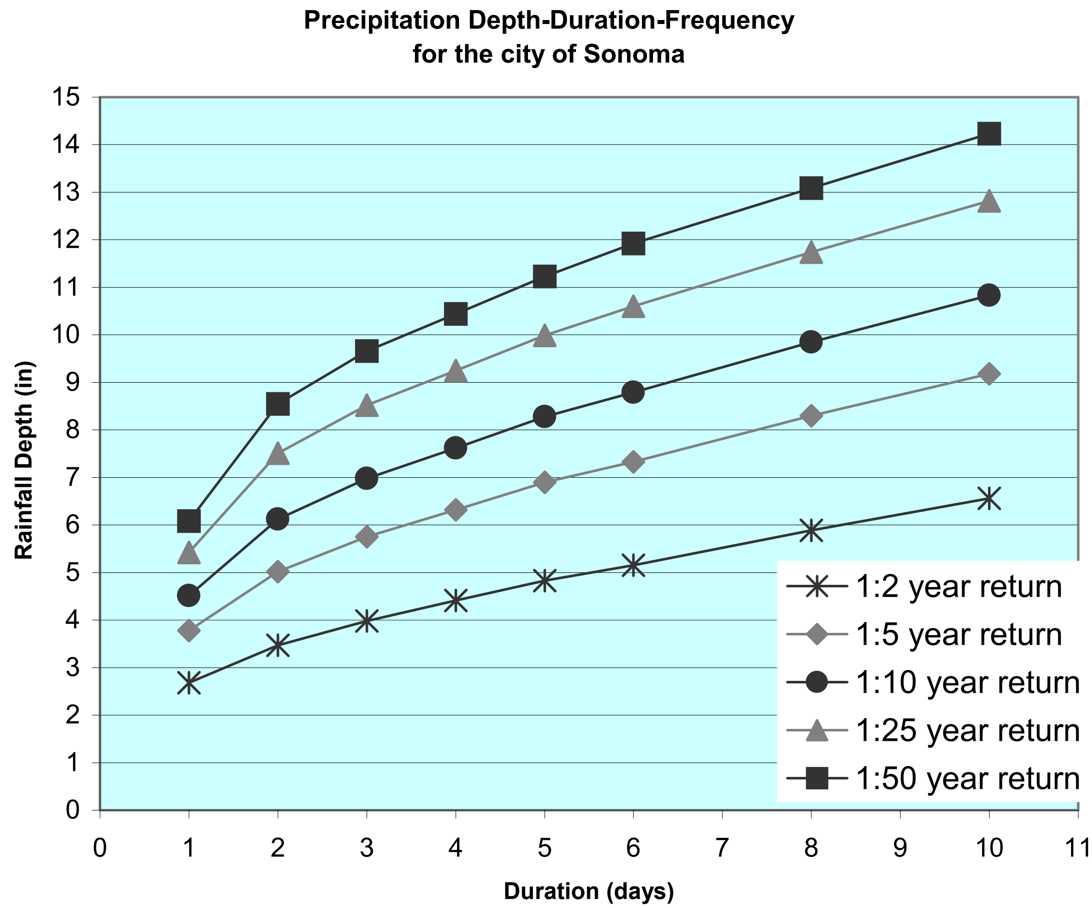


Figure 9. Duration and magnitude of rainfall for a given return period in the City of Sonoma.

return interval of about once in ten years. A second storm occurred a few days later. After 12 days, 12.6 inches had fallen at Sonoma with a return period of 50 to 100 years.

Surface discharge

General description of data

Topography has a major influence on both rainfall (through the effects of orthographic uplift on droplet formation in clouds passing over a watershed) and the transmission of runoff (as a result of slope and roughness). Stream slopes are variable in the Sonoma Creek watershed. Slopes are negligible in the marshland reach, about 10 feet per mile near Schellville, and about 20 feet per mile between Sonoma and Schellville. Slopes are 25 feet per mile between Eldridge and Sonoma, 30 feet per mile from the mouth of Adobe Canyon to Eldridge and increase to up to 300 feet per mile in the headwaters (Corps of Engineers, U.S. Army, 1956).

The SFEI database contains USGS blue line streams for the entire North Bay including the Sonoma Creek watershed. These consist of 1-meter digital ortho-quads (DOQ's), National Hydrography Data Set (NHD) "blue lines" and Digital Elevation models (DEM's). The coverage's are edge matched and include non-connected water bodies. Sonoma Ecology Center's GIS database has hydrology coverage's that include linear and area water features. They are attributed by feature type (e.g., lake, river, marsh), status (e.g., intermittent, perennial), and name. Supplemental locations of wetlands can be acquired from the US Fish and Wildlife Service National Wetlands Inventory. The SEC database also includes the Sonoma Flood Plain coverage by FEMA, and it can be queried by zone, community, and floodway.

A volunteer program overseen by Sonoma Ecology Center is currently collecting discharge data. Volunteer monitoring data of storm events from 1998-1999 and 1999-2000 are currently being analyzed. Trained Stream Stewards used methodology detailed by Luna Leopold for stage and velocity, conducted at surveyed stream cross-sections. Monitoring locations are at 12 representative sites throughout the watershed above tide line (Figure 10). As might be expected

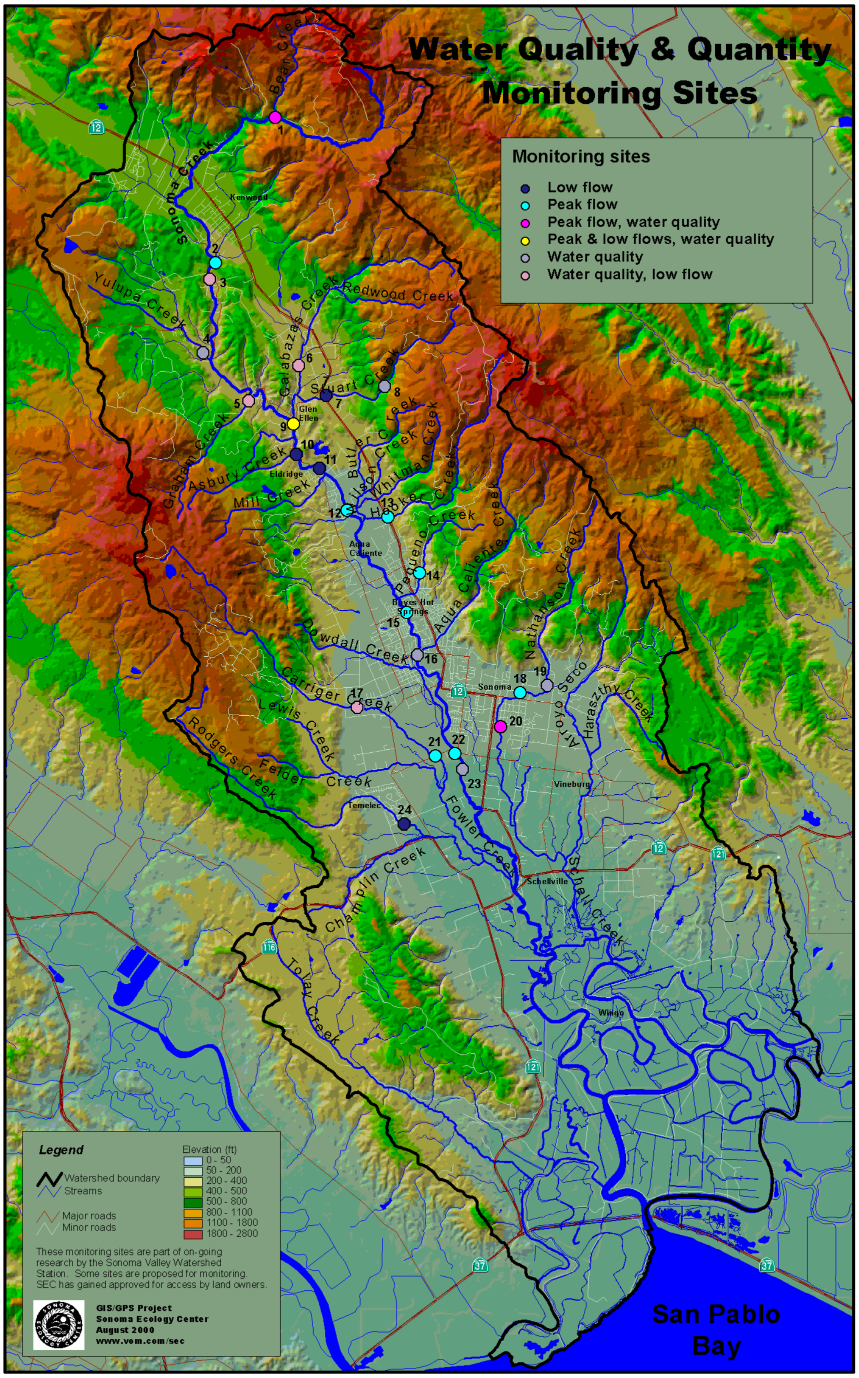


Figure 10. Sonoma Ecology Center Water Quality & Quantity Monitoring Sites.

for a new volunteer monitoring program, SEC has some concerns about the consistency and quality control of these data and the usefulness due to lack of true peak measurements and velocity measurements. After analysis and review, the Center may be revising the protocols.

Historically, USACE (1939) suggests that there were no records of gauging prior to 1939 except a reconnaissance study by the USGS in 1913 during the summer months but gave no data or reference therein. An anonymous source (Anon. 1957) describes six discontinued discharge-measuring stations (USGS and Sonoma County Flood Control District) in the Sonoma Creek watershed and data from them in the 1950's (Sonoma Ck. at Adobe Canyon, Sonoma Creek at Kenwood Bridge, Calabazas Ck. upper, Calabazas Ck. lower, Caliente Ck., and Sonoma Creek near Boyes Hot Springs). The same anonymous source (Anon. 1957) also includes a volume of historical analysis and raw data of the runoff responses of these stations such as storm hydrographs, unit hydrographs, flood-wave velocity, travel times, estimates of 100 year flood flow). The Sonoma County Flood Control District and the Water Conservation District had several sites were stage and flow records were made, and there was a crest -stage station on Sonoma Creek, below Bear Creek established in 1957 by a USGS cooperative program (Anon. 1965). On 24th February 1959, this gauge recorded its maximum discharge of 1500 cfs from the 6 square mile watershed area upstream. Based on correlation with sites on the Napa River, it was determined that the Bear Creek location had a 30% probability that a discharge of 6,000 cfs was exceeded and a 10% probability that a discharge of 9,000 cfs being exceeded.

The following table (Table 2) was compiled using information from the Sonoma Valley Soil Conservation District (1965). Although it is based on information similar to the other texts of the time, and therefore certainly suffers from the problems associated with predictions from short recording periods, it serves as a summary of the likely discharges, at that time, and under those land-use conditions, from different parts of the watershed and maybe useful for comparisons if a data collection effort was resumed in the near future.

Table 2. Discharge characteristics of the Sonoma Creek watershed as determined in the 1960's (Sonoma Valley Soil Conservation District 1965).

		Drainage area	Annual Rainfall	Flood peak discharge		Total annual discharge
		(Sq mi)	(Inches)	(50-yr cfs)	(100-yr cfs)	(Acre-feet average)
Sonoma Ck.	At Bear Creek	7.6	40	1,900	2,200	6,700
	At Boyes Hot Springs	62.7	37	15,100	17,500	
Calabazas Ck.	At dam site	3.5	38			2,840
	At mouth	12.4	38	3,000	3,400	
Agua Caliente Ck.	At dam site	4.2	34			2,940
	At mouth	5.0	34	1,100	1,250	
Carriger Ck.	At dam site	5.8	32			2,830
		11.5	30	2,185	2,540	
Rogers Ck.	At dam site	3.4	26			1,840
	At mouth	8.0	24	1,140	1,410	
Tolay Ck.	At dam site	9.5	24			4,275
	At Hwy 37	9.7	22	1,370	1,600	
Nathanson Ck.	At dam site	2.7	32			1,670
	At Sonoma	4.7	30	900	1,035	

Annual discharge

Surface discharge was continuously recorded at Agua Caliente on Sonoma Creek (USGS station number 11458500) (Figure 11). Runoff (in response to rainfall) occurs on a seasonal basis and is typified by rapid changes in flow. Vary low discharge years occurred in the 1976 and 1977 calendar years in response to very low winter rainfalls. Total annual discharge of the creek from 1955 to 1981 ranged from a low of 1,000 acre-feet (326 million gallons) in 1977 to a high of 114,000 acre-feet (37,100 million gallons) in 1956. It is unfortunate that this recording gauge was discontinued. SEC is presently in the process of re-establishing a discharge record at the historical gauge site to continue monitoring discharge on the main-stem of Sonoma Creek.

Normalized discharge and runoff coefficients

Normalized runoff for the climatic years on record varies from 0.33 inches to 37.68 inches (Figure 12). The 1976 and 1977 drought years are further exemplified by figure 12. The runoff coefficients for the Sonoma Creek watershed above Agua Caliente have been calculated by dividing runoff discharge volume by the volume of incident rainfall (David Leland, SEC 1997). Leland estimated a runoff coefficient for 1956 climatic year of 58% (34 in.) (Figure 13). His estimate for the driest year (1977) was only 2% (0.3 in.) of incident rainfall. In 1977, the driest

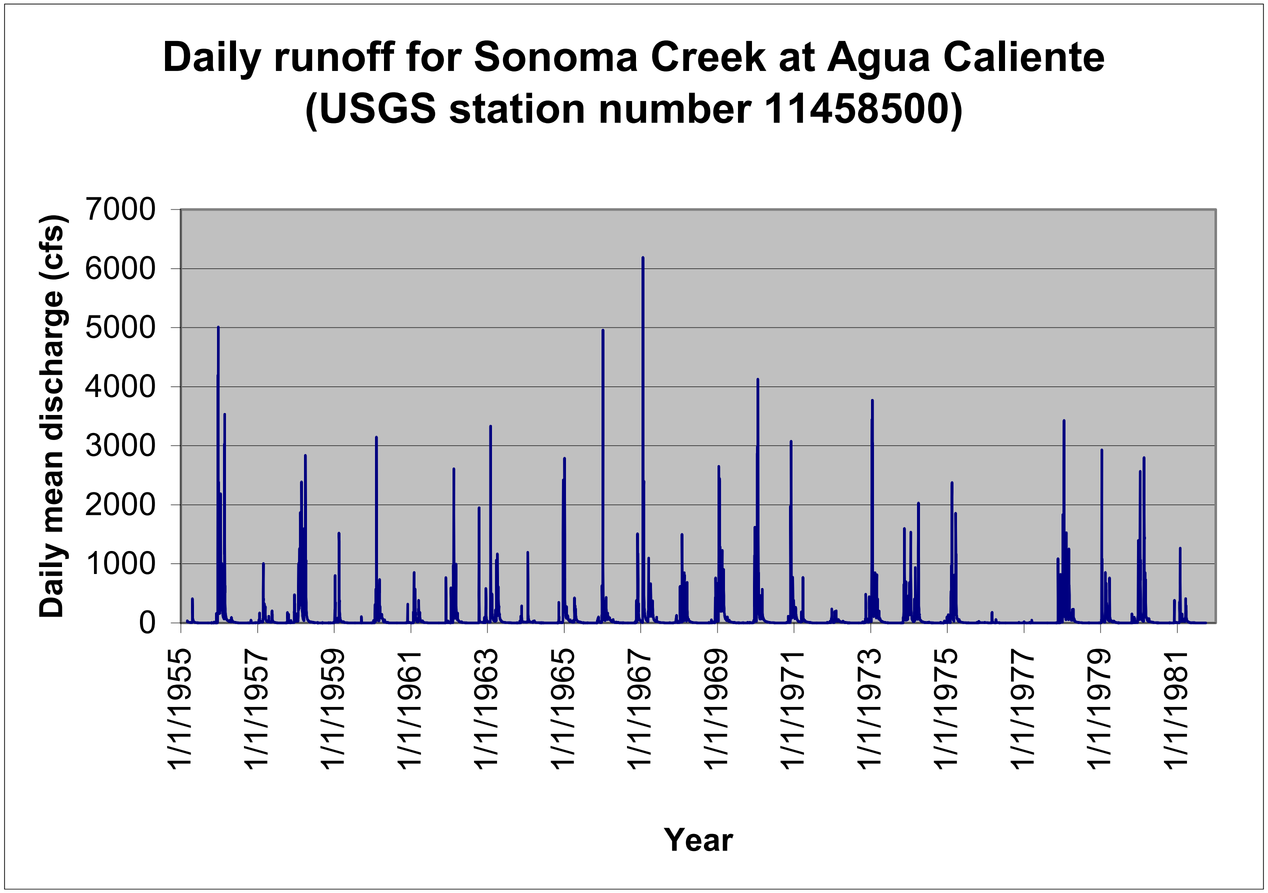


Figure 11. Daily runoff on Sonoma Creek at the discontinued runoff measuring point at Agua Caliente (formally Boyes Hot Springs). Note that these are daily averages not daily peak discharge and therefore this graph does not reflect the true magnitude of the event but it does reflect the timing.

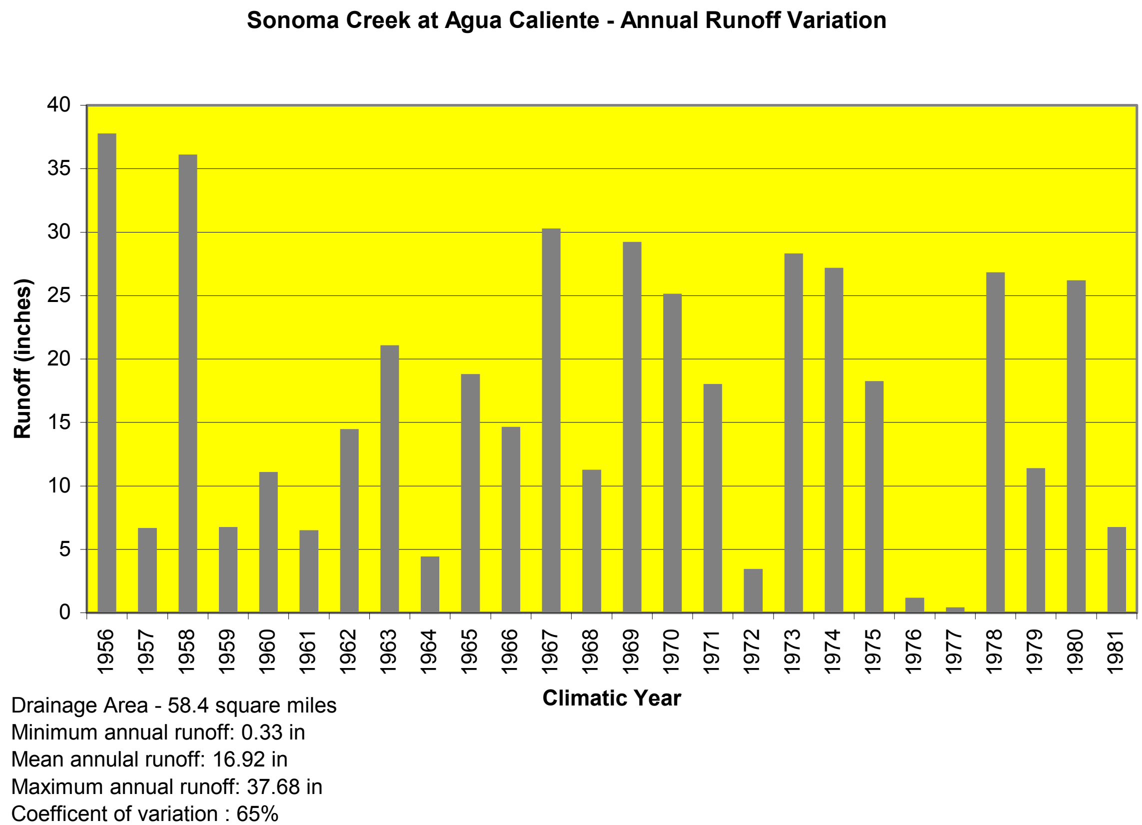


Figure 12. Annual area normalized runoff variation for the period of record at Agua Caliente on Sonoma Creek. Year on the graph are dated by the end date of the climatic year. For example, the December 1955 Flood in included in the 1956 climatic year.

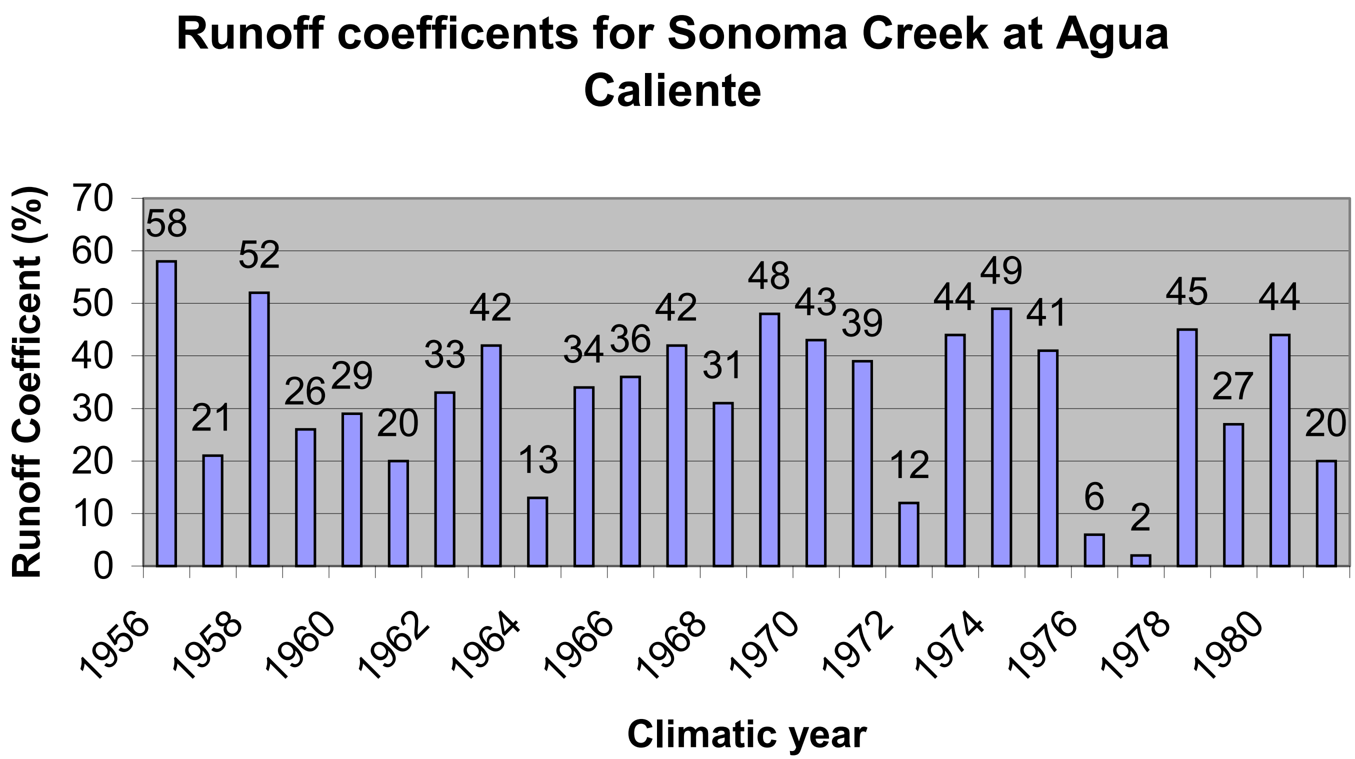


Figure 13. Annual runoff coefficients for Sonoma Creek at Agua Caliente. (David Leland, SEC 1997).

year of the record, no flow was recorded at the gage in most of June and all of July, August, and September. In years of vary low rainfall, the annual runoff coefficient decreases to almost zero. This is because any rainfall that intercepts the watershed is either evaporated or transpired, or recharges soil moisture and groundwater. Only very small amounts are transmitted via the groundwater system or minor surface flow to the stream network.

Dry season runoff

Sonoma Creek has a very low flow during the dry season and can be completely dry during July, August or September (Sonoma Valley Soil Conservation District 1965). Anecdotally, there is consensus in the community that flows during the dry season are decreasing over time (SEC 1997). The lowest low flows are critical in determining the ability of many types of aquatic life to survive over the summer dry season. During the dry season, from May to September, flows at the Agua Caliente/Boyes gauging sites were less than three cubic feet / second (1340 gallons per minute) over half the time. In order to test if dry season flow changed during the period of USGS gauging, the annual minimum discharge (90 day running mean) was graphed with time for the period of record (Figure 14). The analysis proves inconclusive due to inter-annual variation. Dry season discharges did not consistently decrease during the period of record at Agua Caliente. Dry season flows may, however, have decreased since then but there are no continuous data. The analysis was performed using the lowest flow for a 90-day period for each climatic year. However, this does not necessarily correspond to any biologically significant period – it was picked arbitrarily. Secondly, flow on the main stem of the creek may not be as sensitive to factors that may have caused reductions in dry season flow. Smaller first and second order creeks at elevations above the main valley floor may be better indicators.

SEC began a program of systematic data collection in summer 2000. Based on DFG records, anecdotal evidence, and staff observations, twelve low-flow monitoring locations were selected that are proximal to known steelhead nursery habitat and, where possible, under bridges with abutments where staff gauges could be installed. Student interns have been trained to use a flow meter and top-setting wading rod for gauging open creek flow. Field visits will continue until the rainy season begins. Staff gauges will be installed at selected stream flow measurement stations,

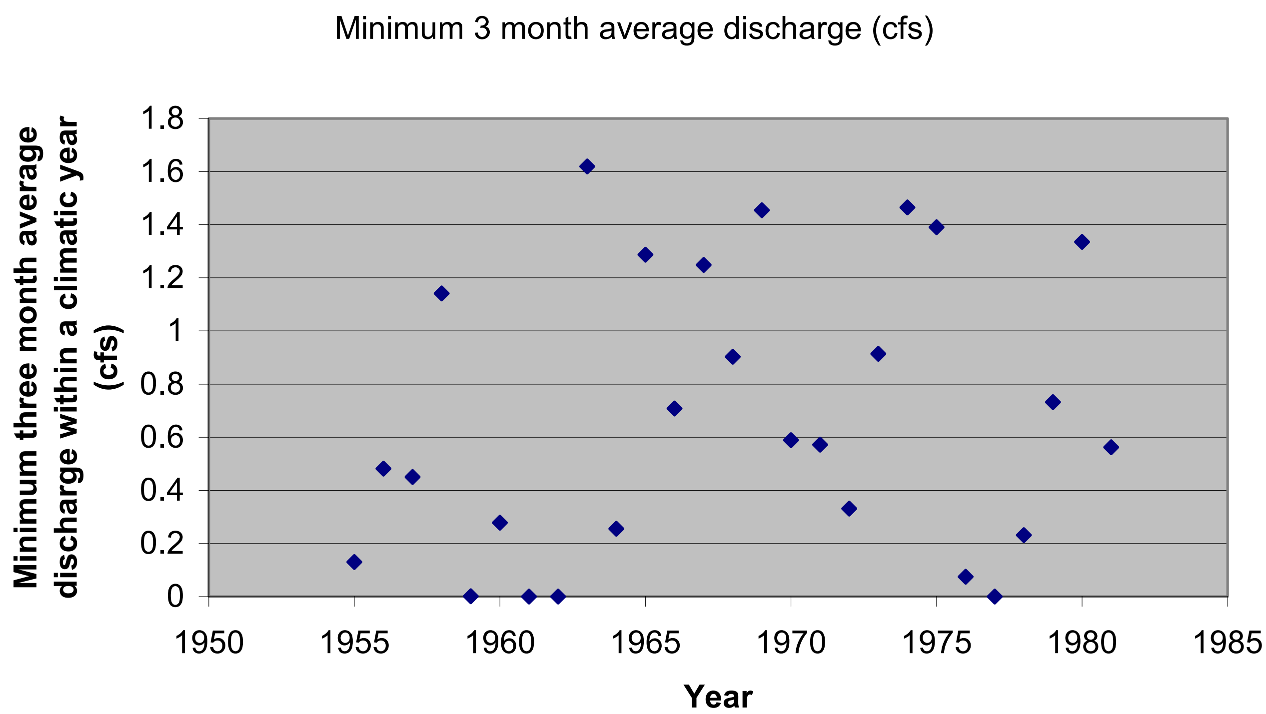


Figure 14. An analysis of dry season flow at Agua Caliente. Each data point represents the minimum three-month average discharge for any given climatic year. The minimum flow was also graphed and didn't show a downward trend.

and rating curves developed to correlate stage with discharge. Data for 2000 should be ready for use by winter.

Watershed response to storm rainfall

Flooding in Sonoma Valley results from intense short-period rainfall that occurs within a storm of longer duration (Sonoma Valley Soil Conservation District 1965). The time of concentration is relatively short (usually <6 hours), and flooding above Schellville is of relatively short duration. However, in the reclaimed areas and areas affected by tidal action from San Pablo Bay, the water may gather for one to four weeks before drainage pumps are able to return the water to the creeks where it finally dissipates on the outgoing tides (Sonoma Valley Soil Conservation District 1965). In addition to this fairly logical and normal flood response, there are further complexities associated with soil moisture conditions that lead to variation in flood response depending on the time of year, period of time since the last flood rainfall, and the rainfall (antecedent groundwater storage conditions) in the year prior to an intense rainstorm. From Leland's analysis (SEC 1997) it is noted that the wettest year did not yield the greatest runoff coefficient. For instance, years during which there are many rainstorms, soil moisture progressively increases with each event. These years will typically display a higher runoff coefficient relative to rainfall than years where there was only a single storm event. For these reasons, in years when there are many rainstorms, the chance of flooding increases with each storm.

In order to better understand the response of the Sonoma Creek watershed to storm rainfall, the three largest storm events based on daily mean discharge were analyzed. Event 1 occurred in January 1967 (Figure 15). On January 20th1967, 4.05 inches of rainfall occurred, and the following day a further 3.8 inches fell. Discharge also peaked on the second day, as did rainfall. By the end of the storm period that lasted 12 days and had two discharge peaks, 1,678 million cubic feet of water was discharged through the Agua Caliente gauging station representing 82% of the incident rainfall (average of Sonoma Town and Saint Helena rain measuring stations). Based on the peak instantaneous gauge height of 13.1 feet at the gauge (104.28 feet above NGVD), this event was the 7th largest for the gauging record based on the partial series.

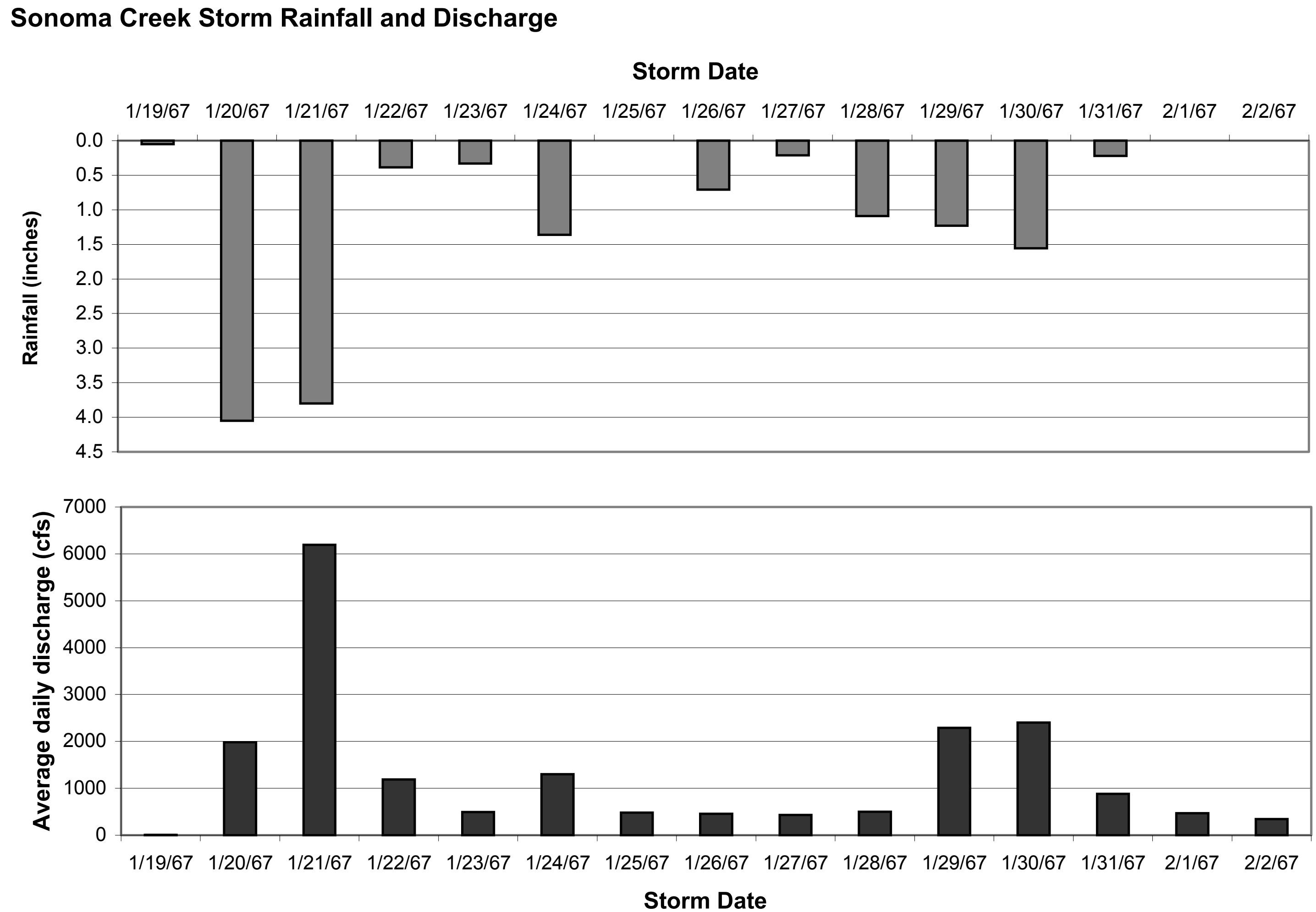


Figure 15. January 1967 storm in Sonoma Creek Watershed.

Event 2 was a triple peak rainstorm and occurred in December 1955 (Figure 16). Peak daily rainfall occurred on 22nd December as did peak discharge. Rain occurred over 11 days. By the end of the event, 1,915 million cubic feet of water was discharged, representing 81% of the incident rainfall. Based on the peak instantaneous gauge height of 17.1 feet at the gauge, this event was the largest on record for the period 1955 to 1981.

Event 3 occurred in late December 1965 and early January 1966 when rain fell over a 13 day period again producing two rain and runoff peaks (Figure 17). Runoff peaked on 5th January in response to two days of heavy rain. This event was the 5th largest for the gauging period (13.6 feet peak stage height at the gauge) and produced 1,011 million cubic feet of discharge representing 81% of the incident rainfall.

What is confirmed from these simple analyses is that the response time of the Sonoma Creek watershed to storm rainfall is less than 1 day. Unfortunately, rainfall and runoff data were only available at the resolution of one day, so it is not possible to conduct an analysis of watershed response time relative to the size and center of mass of the storm rainfall. Analysis carried out in the 1950's (Anon. late 1950's) suggested a response time (time of concentration) of between five and seven hours at Boyes Hot Springs (Table 3). A report by the Army Corps of Engineers (Anon. 1965) also suggested a time of concentration of 6 hours or less. Given the increases in impervious surfaces associated with urban development since that analysis was conducted, it seems likely that the contemporary response time may be <5 hours.

Table 3. Historic data from Anon. (late 1950's) describing runoff character in Sonoma Creek watershed. It is almost certain that runoff character will have changed in response to land-use changes over the past 40 years.

Sub-watershed	Drainage area (sq. mi)	Channel length (miles)	Time of concentration (hours)
Calabazas Ck. at Nuns Canyon Reservoir	3.5	2.8	2.0
Caliente Ck. at Caliente Reservoir	4.2	4.1	2.5
Sonoma Ck. at Bear Ck. Reservoir	7.6	4.3	2.5
Sonoma Ck. at Glen Allen Reservoir	29.8	10.7	5.0
Sonoma Ck. at Boyes Hot Springs	62.7	16.3	6.8
Sonoma Ck. at El Vera no Bridge	68.5	17.2	6.8
Calabazas Ck. at SCFCD Gage 6-6-9	3.9	4.0	2.5
Calabazas Ck. at SCFCD Gage 5-6-1	4.6	5.0	3.0
Sonoma Ck. at SCFCD Gage 7-6-20	7.8	4.6	2.5
Sonoma Ck. at SCFCD Gage 7-6-32-1	16.2	7.1	3.8

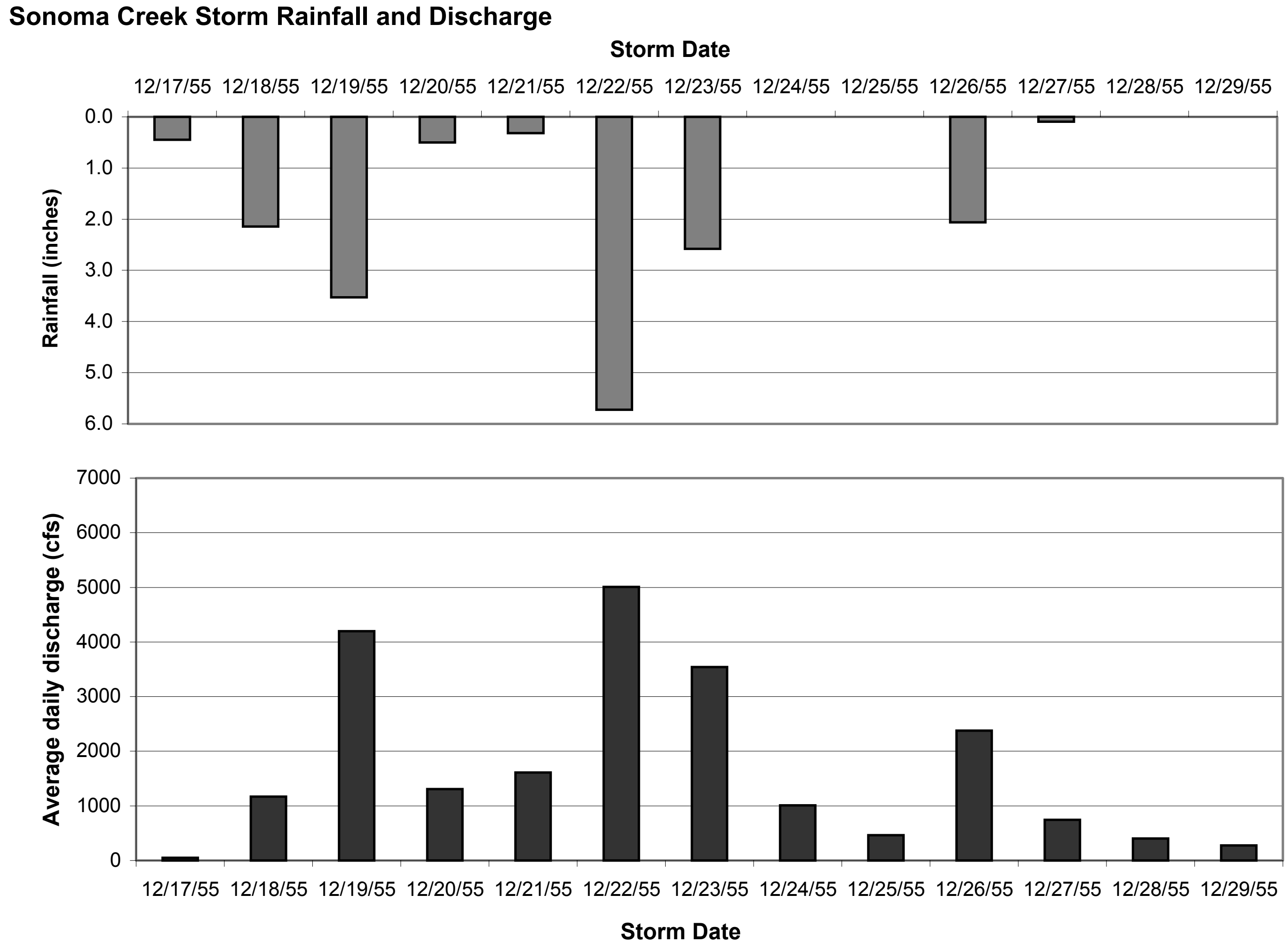


Figure 16. December 1955 storm in Sonoma Creek Watershed.

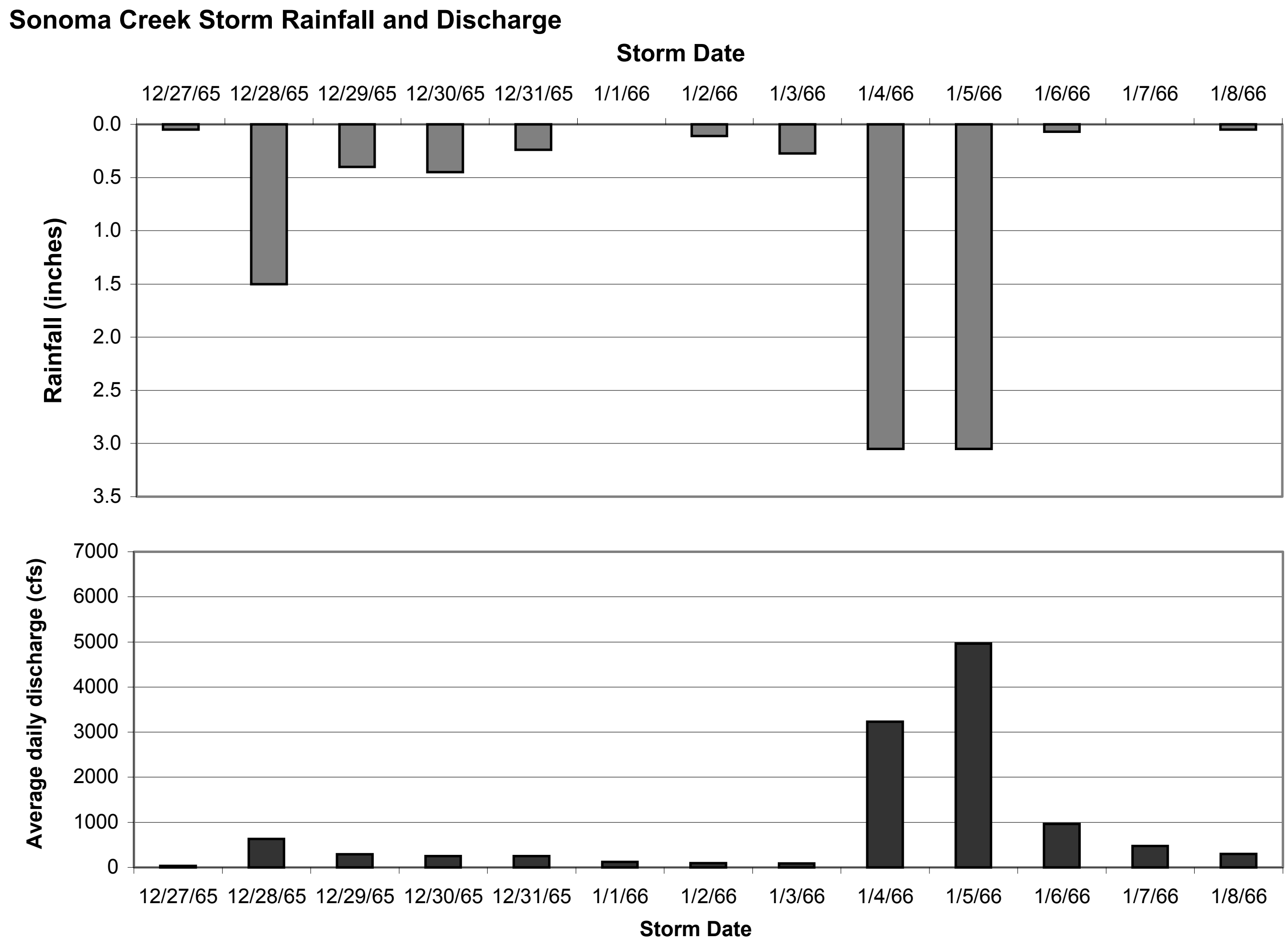


Figure 17. December 1965 / January 1966 storm in Sonoma Creek Watershed.

Return period of floods

An analysis of the return period of floods was conducted using available peak gauge height data for the Agua Caliente station based on the annual series (maximum flood peak for any given year). This analysis suggests that the flood peak that occurred on 22nd December 1955 had a return period of 1 in 27 years. This agrees reasonably with David Leland who estimated this flood to have a return of 1 year in 25 (SEC 1997). Based on the rainfall analysis, this event corresponds to an approximately 1 in 15-year event. The discrepancy is due to antecedent soil moisture conditions in the watershed. Although the previous climatic year had been relatively dry, (28% less the average rainfall in the town of Sonoma) there had been rain for the previous five days prior to 22nd December 1955 and an initial discharge peak on 19th December of 4200 cfs (average for the day) with an instantaneous peak stage height of approximately 11.7 feet.

Given the short length of record, it is difficult to judge the true return interval of floods of a given magnitude in the Sonoma Creek watershed (Figure 18). There are two locations where peak gauge height data are available, Sonoma Creek at Kenwood (USGS 11458400) and Sonoma Creek at Agua Caliente (USGS 11458500). There are 16 years of data a Kenwood and 26 years of data at Agua Caliente. A working paper prepared by the U.S. Army Corps (USACE 1972) also suggested that the December 1955 flood was the largest on record. This report suggested that the return period of this flood was 1 in 13 years, however, there was no reference to the methods used to determine this result and it was probably restricted by a short period of data.

The longest running station in the northeast San Pablo Bay watersheds is Novato Creek with 52 years of data. However, its small drainage area (17.6 sq mi), flow regulation by Stafford Lake, diversions for water supply, and augmentation from the Russian River may limit its usefulness for comparisons. There was no record for the Napa River at the time of the 1956 flood; the largest flood on record for the Napa watershed occurred in March 1995, and 1982 and 1983 were extremely wet years in terms of total runoff. David Leland (SEC 1997) suggested that the January 1997 flood had a return interval of 1 in 3 years although it is not evident how that analysis was done. This contrasts with the same flood on the Napa River that had a return of 1 in 13 years based on 39 years of data. Although there are likely to be differences from one valley to

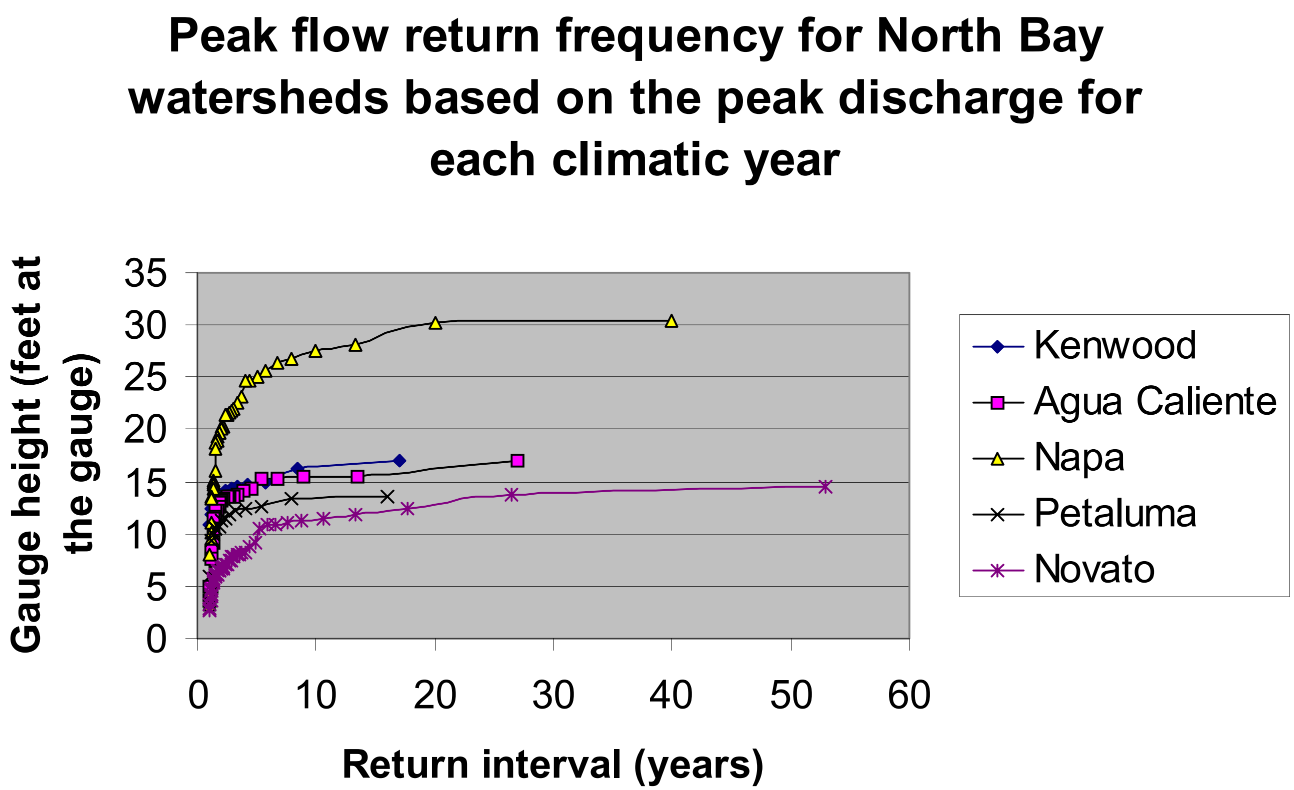


Figure 18. Return interval of floods in the North Bay watersheds for a selection of gauging stations.

the other, we suggest that accurate determination of return frequency of floods in North Bay watershed is severely diminished by short gauging records.

Flooding and inundation

Flooding has been a part of life in Lower Sonoma throughout its history. Even in 1903 when the sloughs were bigger, the water bypassed in the Schellville area (article in the Sonoma Index-Tribune, date unknown). Flooding during the December 1955 flood inundated about 6,300 acres exclusive of the un-reclaimed marsh area adjacent to the Bay (Sonoma Valley Soil Conservation District 1965; USACE 1972). The 1958 and 1963 floods are estimated to have inundated about 4,500 acres and 2,200 acres respectively (Anon. 1965). The standard project flood (20% greater that the 1% flood) would have an estimated peak discharge at Boyes Hot Springs of 22,000 cubic feet per second (about 2.5 times the discharge of the December 1955 flood) (USACE 1972). The standard project flood is a simulated flood that was developed by taking the December 1955 atmospheric conditions that produced that storm rainfall (which were in fact centered 35 miles to the northwest of Sonoma over Cobb and Geyserville) and transposing them directly over the Sonoma Valley. This produced a valley average storm rainfall of 14.4 inches, 63% of which became excess runoff (Sonoma Valley Soil Conservation District 1965). USACE (1972) also mentions other floods that caused major damage, which occurred in 1925, 1937, 1940, 1942, and 1952. A report on Sonoma Valley application for assistance under Public Law 566 (Anon. 1957) mentioned that flooding occurred 10 times between 1921 and 1942 and a further two times (1945 and 1952) between 1942 and 1954. Anecdotal estimates by residents suggested that high water stage of the 1925 flood exceeded that of the 1955 flood by 0.3 feet in the area near Schellville (Anon. 1965). At this time, it was determined that the 1955 flood had an excedence of 10% illustrating the difficulty of flood estimation with short records.

In the reclaimed tideland area below Schellville, the flood damage is primarily from inundation due to local sedimentation. The land there is protected from tidal flows by dikes, which retard the dissipation of floodwaters, and therefore result in prolonged inundation (Anon. 1957). On the floodplain above the tidal land, several hundred acres of land can be flooded for several days below the town of Sonoma, and cleanup is considerable. Bank erosion occurs in localized areas along Sonoma Creek and some of its tributaries (<5 acres on average per year), and flooding occurs where tributary creeks cross the valley floor (notably Nathanson in and below the town of Sonoma) (Anon. 1957). In the December 1955 flood, Tubbs Island suffered flooding associated with high flows in Tolay Creek (Anon. 1965).

The Federal Emergency Management Agency (FEMA) maps areas that are inundated by floods. The County areas prone to flooding by a one-in-100-year flood can be viewed at http: / / www.esri.com / hazards / index.html, and explanations can be read at http: / / www.fema.gov / . Surprisingly, the map for the lower Sonoma Creek watershed does not show any flood inundation for the area around Schellville. The USGS published 1 in 100 year flood-prone-area maps on the Sonoma and Sears Point Quadrangles (USGS 1971a, b). These maps suggest a flood-prone area that includes the lower parts of Rogers and Fowler Creek sub-watersheds below the 30-foot contour, Sonoma Creek downstream from Watmaugh Road, lower Schell Creek, and Arroyo Seco Creek below the 20-foot contour. Near Schellville, the predicted area of the 1 in 100 year flood is about 1.5 miles wide (east-west). The accuracy of the USGS maps is unknown given the short periods of discharge records in the Sonoma Creek watershed. However, the USGS representation of the 100-year floodplain is closer to anecdotal reality than the FEMA map for the area displayed on the Internet.

Discussion of freshwater runoff issues

Definition of the Flooding Problem

In hydrology, he term “flooding” usually refers to a flow of water beyond the stream channel bank or levee and onto the flood plain. In the San Francisco area, a natural fluvial system would normally flood about two in every three years (Dunne and Leopold 1978). However, when discussions are widened to include the interactions of people with floods, the hydrological definition of flooding based on statistical analysis or magnitude and frequency may be unsuitable. A more accurate definition will relate more to the human interactions with floodwaters. For example, flood problems may be defined by:

1. Water inundating a road for a certain number of days bringing about isolation of some properties
2. Water coming over a levee destroying crops or property. A certain size flood during one season of the year may do more damage than in another season of the year depending on stages of plant growth or farming practices
3. Water flooding the basements of houses

At the technical advisory meeting (30th August 2000), the definition of flooding in the lower Sonoma Creek watershed was discussed at length. It was suggested that before any project to reduce flooding is initiated, with the objective to improve the effectiveness of methods to reduce flooding, the problems associated with flooding, and therefore the definition of flooding must be better defined. The following procedure could be followed provide the best information:

1. Use satellite imagery to accurately record the timing and distributions of floodwaters around and downstream of the Schellville area. Images should be taken at least daily (ideally twice daily) for the first two days of flood inundation
2. Conduct one-on-one interviews with residents and landowners in the flood-affected areas immediately after flooding to determine the physical and social effects of flood of a given magnitude and distribution. This approach could also be used to assess effects of particular historical flood events
3. Construct a specific definition of the flooding problem and specific objectives for flood reduction that are agreeable to all parties, before evaluating flood reduction alternatives

Rainfall and Runoff

Currently, long-term rainfall records for the Sonoma Creek watershed are limited to daily summations. Rainfall records indicate short -term climatic shifts of generally drier weather, the most recent of which lasted for an eight-year period from the mid-eighties to the early nineties. Rainfall records also indicate that the Sonoma Creek watershed also undergoes generally wetter periods. However these are less persistent, usually only lasting for up to three years at a time. In spite of the shorter persistence, these strings of wetter years are associated with seven out of the ten largest floods during the gauging record at Agua Caliente.

Discharge was recorded at Boyes Hot Springs and then shifted a few miles upstream to Agua Caliente. The record between 1955 and 1982 shows an annual coefficient of variation of 65%. This is typical of other watersheds in the North Bay (e.g. Napa River at Saint Helena 73%). Given that there was no long-term climatic variability evident from rainfall records, there is reason to assume that the discharge record for Sonoma at Agua Caliente was typical of that period. Using rainfall records from the Sonoma Developmental Center Water Treatment Station, an average runoff coefficient (runoff and a percentage of rainfall) of 33% was calculated by Leland (SEC 1997). For the same reasons it is assumed this would be typical for the period of record. However, given the strong relationship between runoff as a percentage of rainfall and the percent of impervious surfaces associated with urbanization, it seems likely that there many have been increases in both peak discharge and total discharge volume (Figure 19) and reductions in groundwater recharge. Therefore, caution must be exercised if these data are used for estimating the current runoff character of the Sonoma Creek watershed.

As an example of this phenomenon, an analysis was done on the gauging data from Napa River near Napa by taking the first 19 years of data and comparing it to the second 19 years of data (Figure 20). This indicates that for a given gauge height the return interval in the later period has decreased. For example, a flood stage that once occurred one time in every ten years now occurs once every five years. This has either occurred because of a climatic increase in rainfall or because land-use conversion has increased runoff. Although the average rainfall was 3 inches greater in the second period relative to the first, an ANOVA showed no significant difference in the means at the 1% level. It is suggested that both a slight increase in rainfall and, more likely, the changes in land-use have caused the changes in runoff. A similar analysis was performed for Napa River at Saint Helena. In this case, the longer record of data were broken into three 19-year periods. The average rainfalls for each period were: 1940-1958 = 37 inches, 1959-1977 = 36 inches, and 1978-1996 = 38.5 inches. Given the changes in climate are only slight, it seems likely that changes in land-use is the cause of changes to recurrence interval. Again, ANOVA showed no significant difference between the three intervals at the 1% level. Another possibility is that the channel cross sections of these river stations may have changed in geometry

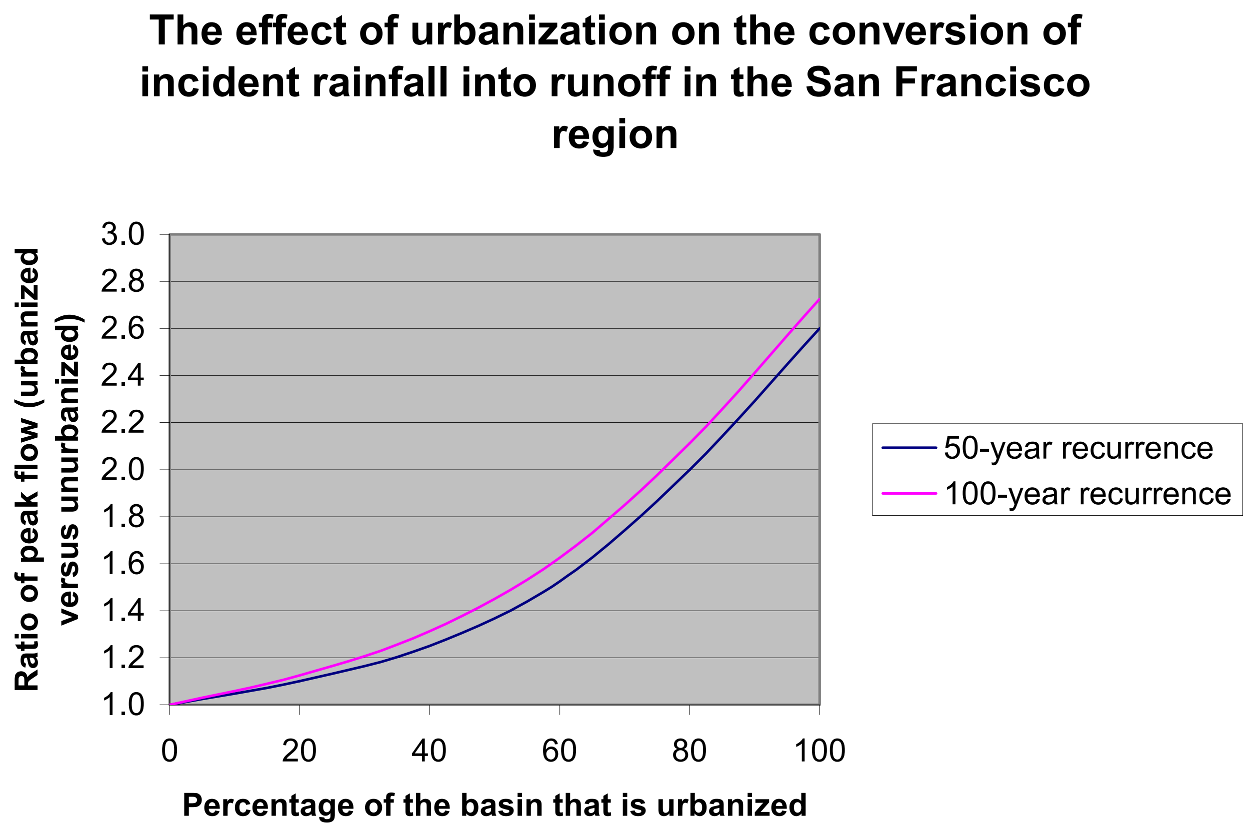


Figure 19. The effect of urbanization on peak runoff. Urbanization affects the peak flow of the watershed by increasing the area of impervious surfaces. In those areas of the watershed where conversion to urban land use is taking place, more of the incident rainfall will be converted into surface runoff instead of either being intercepted by vegetation or recharging soil moisture or groundwater. After Waananen et al. 1977.

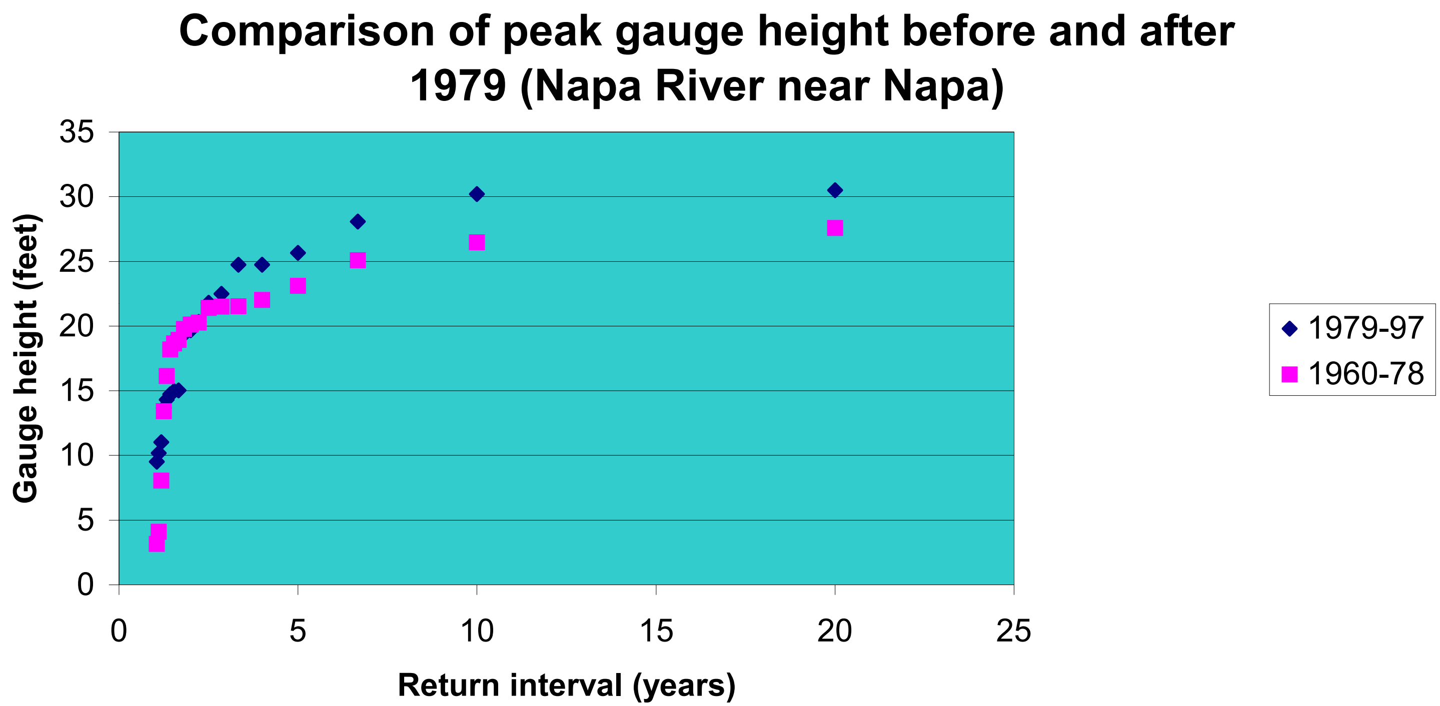


Figure 20. A simple analysis of flood peaks based on the annual series for the Napa River near Napa. It appears that the recurrence interval of flood of a given magnitude has decreased over time. Although there was two inches less rainfall on average in the second 19 years of data, it is hypothesized that the conversion of grasslands to urban and vineyard land use has played an important role also.

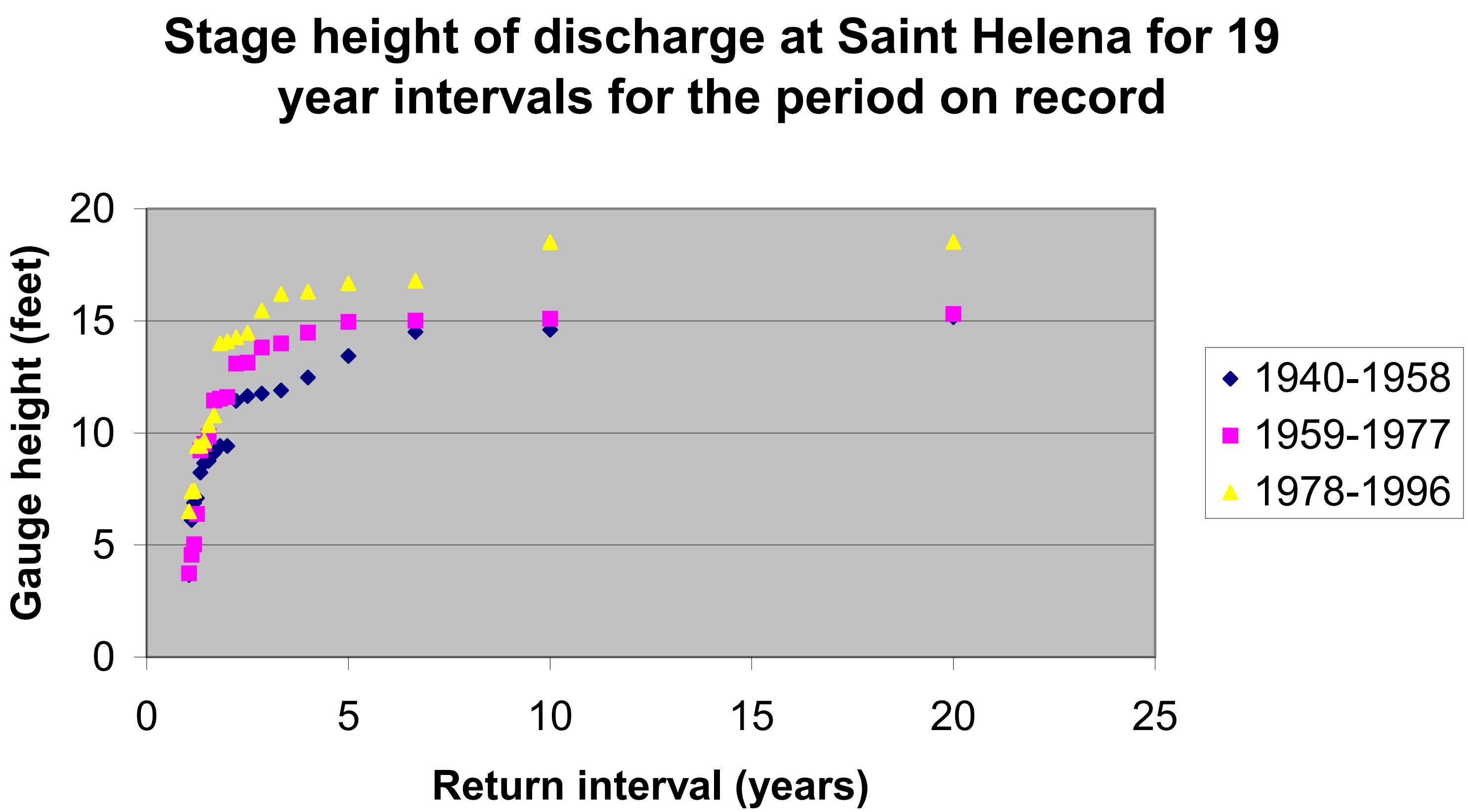


Figure 21. A simple analysis of flood peaks based on the annual series for the Napa River near Saint Helena. It appears that the recurrence interval of flood of a given magnitude has decreased over time. It is hypothesized that the conversion of grasslands to urban and vineyard land use has played an important role also.

causing the observed changes. A more detailed analysis could be done for Napa, however in this report, Figure 20 and 21 serve as a tool for asking the right questions.

The response of the Sonoma Creek watershed to rainfall was between six and seven hours in the 1950's. As land-use patterns have changed and population has grown more than ten-fold since then, it seems likely that the response time now may be less that six hours. Some farmers in the area near Schellville who annually await the flood runoff to come down the creeks during heavy rainstorms also suggest this.

Water delivery, collection, and treatment systems

SEC has a current contract with the Sonoma County Water Agency which includes creating a GIS database of SCWA infrastructure in Sonoma Valley including existing sewer lines, manholes, service connections, recycled water lines, wells, supply lines, flood control facilities, pump stations, and groundwater recharge basins. The hydrology coverage's include a variety of features built for water conveyance, including channels, ditches, dams, reservoirs, etc.

Groundwater

There are two primary groundwater-bearing geologies in the Sonoma Valley (younger and continental deposits and alluvium which are either unconfined or semi-confined) (Sonoma Valley Soil Conservation District 1965). However, the Sonoma Creek watershed is underlain by an assortment of geological materials most of which yield some groundwater of reasonable to excellent quality when tapped (Department of Water Resources 1975). Yields of groundwater to wells drilled into the Sonoma Volcanics are typically slight or nil in dense non-fractured rocks to moderate in fractured areas that are more permeable. The yields from the Petaluma formation tend to be moderate. However, water quality tends to be poor due to dissolved sodium, chloride and sulfate ions. Yields from the Glen Ellen formation may be locally high enough for irrigation use, although permeability in the Sonoma Valley area tends to be poorer than in other areas in Sonoma County. The Pleistocene alluvial deposits tend to be poor producers of groundwater and are frequently impermeable due to a layer of hardpan. The Holocene alluvial fans can be permeable and act as recharge areas for ground water. On the valley floors, younger alluvium provides good recharge to the groundwater table. Modern stream channel deposits are highly permeable and may be locally very important for groundwater recharge if underlain by older permeable strata. Bay mud in the lower Sonoma Baylands is impermeable and of little consequence to groundwater movement, recharge or extraction.

SEC is working in conjunction with the Sonoma County Water Agency to convert well log data from 5000 sites in the valley to GIS-linked database files. A private consultant was retained by Valley of the Moon Water District to conduct a groundwater analysis for the district in 1998 in advance of new District well use. Results of the study indicated a network of fractured aquifers, with a few areas showing stress from overuse, and most areas adequately recharging during high flow. Given sample size and other limits to the model used, a more detailed groundwater study is recommended. It is anticipated that with SEC data from well logs and a new program for volunteer monitored wells, a better understanding of baseline conditions will emerge as new studies progress.

DWR water rights data for upper watershed streams has been collected and linked to GIS base layers. This information, coupled with estimates of evapotranspiration, rainfall, runoff, groundwater, and soil moisture will allow the development of a watershed-wide water budget. A water budget would allow us to understand the proportionate water uses from different sectors of the community (for example use for water supply, irrigation, waste, riparian flow, flood flow, and groundwater storage) and therefore enhance the knowledge on sustainable environmental and economic water use.

Section 4.

Tide gauge location, height, and tide induced flow

Introduction

Tides in San Francisco Bay are diurnal uneven with two tides approximately every 25 hours. The tides in the Bay area are characterized by strong inequality during the neap phase. Tides at the San Francisco gauge at the Presidio (station No. 941 4290) have an average daily range for the smallest tide of the day of 4.1 feet and for the largest tide of the day of 5.83 feet. However, these fluctuate on a reasonably predictable basis between spring and neap sequences in relation to the position of the sun and moon. Climatic systems such as strong coastal winds and low-pressure systems can have effects on the tides in the Bay Area causing deviations from the predicted tides.

Locations of tide gauges

Tide data is collected at many points within San Francisco Bay and in locations in tidal reaches on the major rivers. Tide data is collected by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service (www.co-ops.nos.noaa.gov). Some of the locations that are near the Sonoma Creek watershed include:

1. Petaluma River, upper drawbridge (Station No. 941 5584; 38°13.7’N, 122°36.8’W) for a 12-month period (April 1977 to May 1978). The tidal range for this station was *6.54* feet (Mean lower low water (MLLW) to mean higher high water (MHHW). It was not tied to a datum
2. Petaluma River, Lakeville (Station No. 941 5423; 38°111.9’N, 122°32.8’W) for a 12-month period (April 1977 to April 1978). The tidal range for this station was *6.32* feet (MLLW to MHHW). It was not tied to a datum
3. Petaluma River, Entrance to San Pablo Bay (Station No. 941 5252; 38°6.7’N, 122°29.9’W) for a 22-month period (July 1977 to April 1979). The tidal range for this station was *6.06* feet (MLLW to MHHW) and it was tied to the NGVD 29 datum
4. Sonoma Creek, Wingo (Station No. 941 5447; 38°12.6’N, 122°25.6’W) for a 3-month period (August to October, 1979). The tidal range for this station was 5.87 feet (MLLW to MHHW). It was not tied to a datum

5. Napa on the Napa River (Station No. 941 5623; 38°17.9'N, 122°16.8'W) for a 15-month period (January 1978 to November 1979). The tidal range for this station was *6.66* feet (MLLW to MHHW) and it was tied to the NGVD 29 datum
6. Napa River, Edgerley Island (Station No. 941 5415) for a 5-month period (July to November 1979). The tidal range for this station was *6.30* feet (MLLW to MHHW) and it was not tied to a datum
7. Mare Island Navel Shipyard, Carquinez Straight (Station No. 941 5218; 38°4.2'N, 122°15.0'W) for a 20-month period (September 1985 to April 1987). The tidal range for this station was *5.73* feet (MLLW to MHHW) and it was tied to the NAVD 88 datum

It can be seen from a brief review of the tidal data in the North Bay that tidal variation at Wingo in the Sonoma Baylands is typical of other stations. Although the station meta data on the internet do not show the information relative to either the NGVD 29 or the NAVD 88 datum, it is possible that registration has been done. This should be checked. The Wingo station (a subordinate tide station with a short record) may be able to be modeled if it were tied to a primary control tide station for which continuous observations were made over a minimum of a 19-year Metonic cycle (the period of time that it takes for a new moon and a full moon of a given month to reoccur on the same day). Such a primary control station can be used to calculate harmonic and non-harmonic constants (U.S. Department of Commerce 1975) and these along with a comparison of simultaneous observations may be used to generate tide at Wingo. In order to model tidal water exchange in the lower Sonoma Baylands it is necessary to retrieve tidal data on a no greater than 1/2 hour interval especially if there is a standing wave generated in response to channel geometry (Karl Malamud-Roam personal communication, August 2000).

Tidal velocity measurements

Schladow et al. are currently collecting tidal data as part of the CISNet study (USGS, U.C. Davis, SFEI, and Pt. Reyes Bird Observatory). The primary objective of this study is to determine optimal selection of monitoring stations, temporal frequencies, and chemical, biological, and ecological indicators for long-term monitoring. The CISNet study collects data from 12 locations in the North Bay and it tidal rivers and sloughs. Three of these stations are located in the Sonoma Marsh system and two of the three are fitted with conductivity, temperature, depth (CTD) sensors and a velocity meter. At the intensive stations, CTD and velocity data were being collected on a 15-minute time interval from January to August 1999. In addition data a currently being collected from September 2000 through to March 2001. The two intensive stations are:

1. Sonoma Creek at the mouth approximately 500 feet south of the Hwy 37 Bridge (38°09.15'N, 122°24.28'W) in the center of the main channel
2. Sonoma Creek, 800 feet north of the junction with the second Napa Slough (38°11.5'N, 122°25.65'W) in the center of the main channel

In addition, the third, less intensive station, is:

3. Hudeman Slough, Sonoma Marsh, approximately 0.4 km east of Skaggs Island Road Bridge in the middle of the slough (38°12.27'N, 122°22.22'W)

Concurrent field work will include tidal datum reckoning, tidal elevation control, channel cross section surveys, and tidal prism determinations via current flow velocity meters and recording pressure transducer water level indicators. The CISNet data collected by Schladow et al. would seem to provide excellent data set for any future modeling of tidal processes in the lower Sonoma Creek watershed in relation to both flooding near Schellville or design of restoration projects. It also establishes the base line conditions necessary for post project monitoring and ecosystem response assessments.

The CISNet study postdates another study of direct interest to the lower Sonoma Creek watershed which was conducted in the Napa / Sonoma marshlands during September 1997 to March 1998 (Warner et al. 1999). Data were collected using conductivity-temperature-depth probes (CTD). Current direction and magnitude were measured using electromagnetic current meters (ECM's) and acoustic Doppler profilers (ADP's), and suspended sediment concentrations data were also logged using Optical backscatter sensors (OBS) calibrated by water samples analyzed for suspended sediment concentrations. Data were collected at 17 sites including six with in the Sonoma Baylands:

1. Mouth of Sonoma Creek (38°09'08"N 122°24'17"W)
2. Sonoma Creek north of the confluence with Second Napa Slough (38°09'08"N 122°24'17"W)
3. Second Napa Slough (38°11'29"N 122°25'38"W)
4. Third Napa Slough (38°12'35"N 122°24'46"W)
5. Hudeman Slough (38°12'16"N 122°22'13"W)
6. Napa Slough (38°09'31"N 122°22'35"W)

Warner et al. (1999) concluded that tidal signals propagate from the sides of the Napa / Sonoma Marsh system and encounter each other at a many convergence zones (a zone where tidal waves meet from two difference directions). At each of these convergence zones, the sloughs are narrower possibly due to reduced tidal energy during longer periods of low velocities. This supports earlier work by Collins et al. (1986) who describe the process by which the circular slough systems are formed. Preliminary investigations by Collins et al. suggested that the flows displaced by retrogressed channels are accommodated by other channels that erode. This explains the elongation of some of the small channels in headward reaches of drainage systems where retrogression was also observed. These headward eroding drainage channels can capture each other at a common drainage divide forming the circular sloughs seen today. After capture, the zone of convergence would move in the direction of the time lag. Collins et al. went on to suggest that these processes are dynamic and that sedimentation may produce a new divide and a new convergence zone and thus a successional process of reconfiguration.

Wind forcing influences the residual depth at the boundary sites, with the influence propagating through out the marsh complex (Warner et al. 1999). Freshwater flows caused a net flow towards the boundaries. Residual velocities are generally clockwise in the Sonoma Baylands and anticlockwise in the Napa Baylands. The combination of freshwater inflows, spring-neap tidal cycles, wind, and geometry of the Slough systems modulate the residual velocities. During periods of low freshwater inflow, there is higher salinity and suspended sediment concentration in the Sonoma Baylands than in the Napa Baylands due to the influence of San Pablo Bay. Suspended sediment concentrations remain high during the dry season associated with tidal re-suspension. However, there are pulses of suspended sediment associated with storm discharge from the watershed (Warner et al. 1999).

Further analysis (Warner, 2000) of the data collected in the 97-98 study showed that the time series of water level and velocity measured at sites Pablo, Socr, SNS, Napa and TNS (See Warner et al. 1999 or Warner, 2000 for the locations of these site names) are non reproducible by harmonic analysis. The asymmetry is caused by a truncation of the water level due to the existence of a sill along the northern edge of San Pablo Bay. At low tides, the water level on the seaward side of the sill in San Pablo Bay reduces to match the forcing ocean tide. However, the water level on the landward side of the sill can only reduce to the level of sill. This truncates the lower portion of the water level, creating an extended slack tide, and creating rapid accelerations during the flood current when the water level finally rises above the level of the sill. These effects are most pronounced during spring tides.

What is not well understood is the ultimate source of suspended sediments in the North Bay Sloughs. Is the sediment that is re-suspended on the tides ultimately derived from local watersheds or has it come from the Bay and ultimately from the Sacramento and San Joaquin river basins? Work done in Novato Creek by Laurel Collins found there were large deposits of organic debris in cores. This organic material way derived from the Novato Watershed and formed a large proportion of the length of the cores suggesting that, in Novato, local sources of sediment are more important than Bay sources. Laurel has also observed that the pattern of the largest tidal mudflats appears to be associated with drainages in the Bay Area that are dominated by earth flow landscapes. Very fine sediments / huge sediment loads = large mudflat areas. The question remains how important the local Sonoma Creek watershed is to sediment supply in the Napa-Sonoma-Marsh system. This question seems closely tied to the success of tidal marsh restoration. Does a restoration design in the Sonoma Marsh need to be augmented by dredge materials or will it full up naturally and rapidly by natural sedimentation associated with flooding and tides?

Section 5.
Water quality and sediment quality

Water quality

Watershed

There are at least 62 sampling events available from the EPA's STORET database from 11 sampling sites over a period of 1973 to 1988. Eight of the stations are on Sonoma Creek downstream of Agua Caliente road, there was an upper watershed site at highway 12 on Sonoma Creek, and the last two sites were at Highway 121 on Tolay Creek and on Fowler Creek at Watmaugh road. Most of the sampling was during summer months using grab sampling techniques. Water quality measurements were made for temperature, dissolved oxygen, biological oxygen demand, biochemical oxygen demand, pH, turbidity, total suspended solids, conductivity, total dissolved solids, total and fecal coliform, nitrate, nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, phosphate, total alkalinity, total hardness, calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, silica, and boron. A summary and discussion of these data is provided by SEC (1997).

North Bay watersheds are currently listed as impaired for sediments, nutrients, and pathogens (Clean Water Act 303d). It was noted that there was a significant downstream trend for TKN, and that spring nitrate concentrations averaged 1.6 mg / L and were elevated over summer and fall concentrations (SEC 1997). Although, in relation to human health, these concentrations are not considered high, the trend of TKN and the seasonal trend of nitrate are indicative of an impacted system (McKee et al. in press). Nitrate concentrations in pristine watersheds average 0.11 mg / L (Meybeck 1982). Although there are variations in natural nitrate concentrations, this simple comparison suggests that Sonoma Creek may have several times higher nitrate concentration than it did prior to human intervention. Further, aquatic systems downstream in the San Pablo Bay ecosystem may be severely impacted by excess nutrient discharge if they are more adapted to low-nutrient seawaters. In terms of phosphorus, SEC (1997) noted that phosphate made up 47 to 66% of the total phosphorus in Sonoma Creek watershed samples. Also noted was an increasing downstream trend in both total phosphorus and phosphate (SEC 1997) - also indicative of an impacted watershed. Concentrations in the downstream waters exceeded recommendations for healthy aquatic ecosystems.

SEC has monitored summer water temperatures with HOBOtemp automated monitors since 1996 at three to twelve sites in pools in Sonoma Creek and major tributaries. Analysis of the data indicates that water temperatures at all of the monitored locations are suitable for rearing steelhead and are not likely to be a significant factor limiting distribution in the watershed. However, water temperatures are not optimal at most locations. A full report, including data from 1998, and raw data from 1996 through 1999, are available from SEC; Further details can also be found in SEC (1997).

Information on the continuous discharge of sediments and pollutants from the Sonoma Creek watershed appears to be relatively sparse. The grab sampling data in the EPA's STORET database is suitable for simple spatial trend analysis and if sampling were continued, longer-term temporal trends may become apparent. Sediment concentrations were collected by the USGS at station 11458500 (Agua Caliente) probably in the 1970's. The raw data were requested from USGS, but no records were found. Anderson (1981) documented this data in a paper that compared long term predicted average sediment discharge from 61 California watersheds. At the time of data collection an average for Sonoma Creek of 162 metric tons per km^2 per year was computed. This compares closely to station 11456000 on the Napa River with a sediment discharge of 215 metric tons per km^2 per year at the time of computation (Anderson 1981). Anderson also developed a statistical model for predicting sediment discharge based on 10 watershed attributes including geology, landslide potential, rainfall, steam flow, slope, topography, and fire. The model explained 73% of the variation in sediment discharge and was used to predict historical sediment discharge providing a baseline for management Unfortunately, the example he gave was not for Sonoma but it may be possible to replicate the work and produce an historical estimate for Sonoma.

In regard to sediment bed load, there does not appear to be any data available from the USGS although there is a small amount of bed load data available for the Napa River watershed (station Napa River at Napa 1145 8000) that may be suitable for comparisons with any future data collection effort. Geomorphic analysis being carried out on Sonoma Creek just below the discontinued Agua Caliente gauging site suggests that the substrate is bed load dominated (Michael Hughs personal communication July 2000). Laurel Collins (SFEI) is currently leading a geomorphic study on lower Carriger Creek. Her work shows that the channel cross-section in this creek has increased in width by a factor of two times. The scope of the Carriger Creek work did not cover any surveys below the confluence with Fowler Creek therefore it is not possible at this time to determine where this sediment has gone. Substrate bed material in Carriger Creek is variable throughout the survey length. Some areas are sandy and others are course. Determination of what caused changes in geomorphic features in Carriger Creek and an analysis of how much sediment has left the system will help to determine what the causes of flooding are near Schellville.

SEC is using GIS and field-collected hydrologic data to assess hillslope sediment production and characterize erosion rates, beginning in Annadel State Park. The GIS model incorporates factors of the MUSLE (modified universal soil loss equation), including slope, up-slope watershed area, vegetation, soil type, and bedrock geology. These factors are weighted and combined to predict the level of sediment production across the landscape. The predicted sediment production will be calculated in 10-meter cells, and aggregated over sub-watersheds. The resulting maps will indicate areas most prone to sediment production based on physical and biological landscape features. Model predictions will be checked against field data. Sonoma Ecology Center plans to expand this model to the rest of the watershed in the future.

The surface Runoff Management Plan from 1975 contains predictions of discharge of biological oxygen demand, suspended sediments, volatile suspended solids, total nitrogen, and total phosphorus based on SWMM (Storm Water Management Model) modeling with data input from Bay area averages (Sonoma County Water Agency 1977). The modeling suggest SS = 1049 pounds per acre, TN = 4.4 pounds per acre, TP = 0.6 pounds per acre. The models also predicted changes to the year 2000 based on changes in land-use of 0.94x SS, 1.36x TN, and 1.23x TP.

A simple model was used to predict sediment discharges from sub-watersheds in the Sonoma Creek Watershed (SSCRCD 1997). The PSIAC model (Pacific Southwest Inter-Agency Committee) used nine factors to calculate a rating that is then converted into an average sediment yield using a rating sheet derived from empirical data from other watersheds. This model is best used as a watershed-planning tool rather than for predicting reliable estimates of annual suspended sediment yield.

North San Pablo Bay and the Sonoma tidal channels

Water quality data (temperature, transparency, and total dissolved solids) were collected at Hudeman Slough by the Department of Fish and Game, in connection with fish sampling at four-month intervals from October 1973 to June 1976. In 1975 and 1976 two reports on sewage discharge and future requirement and recommendation to meet discharge water quality standard was prepared (Sonoma Valley County Sanitation District 1975, 1976). The main problem at that time was associated with excessive infiltration and storm-water inflow causing the capacity of the plant to be exceeded and untreated wastes to be discharged during storm events. Recommended solutions included modification or enlargement or existing facilities, irrigation, or construction of a new plant. Water quality and salinity data have been collected as part of the Sonoma Valley County Sanitation District - NPDES Self-Monitoring Program in the tidal channels of lower Sonoma (Table 4). These data have been collected on a monthly basis since November 1986. Water samples have been analyzed for ammonia, dissolved sulfide, chlorophyll-a, dissolved oxygen, pH, hardness, temperature, turbidity, and total dissolved solids and possibly metals and pesticides

Table 4. Water quality collection points of Sonoma Valley County Sanitation District - NPDES Self-Monitoring Program.

Station name	Description	Latitude	Longitude
C-7	At a point in Second Napa Slough located at its confluence with Third Napa Slough.	38.24	122.43
C-8	At a point in Sonoma Creek located at its confluence with Second Napa Slough.	38.24	122.43
CS-1	At a point in Schell Slough located at the tide gates upstream from the point of discharge.	38.24	122.43
CS-2	At a point in Schell Slough located within twenty feet downstream from the discharge.	38.24	122.43
CS-3	At a point in Schell Slough located 500 feet downstream from CS-2.	38.24	122.43
CS-4	At a point in Schell Slough located midway between its confluence with Steamboat Slough and the point of discharge.	38.24	122.43
CS-5	At a point in Steamboat Slough located at its point of confluence with Schell Slough.	38.24	122.43
CS-6	At a point in Third Napa Slough located at its confluence with Steamboat Slough.	38.24	122.43

Water quality information was collected in the Schell Slough from June 1986 to February 1987 (Cooper and Cooper 1987). Data parameters collected were total coliform, fecal coliform, fecal streptococci, dissolved oxygen, chlorinity, ammonia, pH, and temperature. Data were collected on between 9 and 16 occasions during the study at seven locations:

1. Sonoma Creek south of Hwy 121
2. Sonoma Creek north of Wingo Railroad Bridge
3. Sonoma Creek south of Wingo
4. Sonoma Creek south of Camp 1
5. Sonoma Creek midway between the Sears Point Bridge and the confluence with the Second Napa Slough
6. Schell Slough south of the Sonoma Valley County Sanitary Discharge area
7. South of the Confluence of the Hudeman and Second Napa Slough

Perhaps the most recent and comprehensive water quality data has been collected by the CISNet study (Schladow et al.), described in the section in this report on tidal information. CISNet collected conductivity, temperature, and optical backscatter on 15-minute intervals for January to August 2000. In addition, the water column and sediment was sampled monthly on comparable tidal phases. Water, suspended sediment, and surface sediment samples were analyzed for a suite of trace metal and organic compounds to determine the health of the benthic community. This information is as per the original proposal. It should be noted that this sort of study is logistically difficult and delays often occur – therefore the original plan may have been modified.

San Francisco Estuary Institute (SFEI) has been coordinating the Regional Monitoring Program for Trace Substances (RMP) since 1993. Until 2000, the RMP has collected water, sediment and tissue samples two to three times per year, at many stations throughout San Francisco Bay. Additionally there are a number of "Special Studies" that address wide-ranging issues in more specific physically, chemically or biologically defined study areas. The RMP has been collecting water quality data in North San Pablo Bay, at the mouth of the Petaluma River, and at the mouth of the Napa River. For example, 1998 wet season (February) salinity at Petaluma and Napa stations reduced to zero during high river flow but during the summer sampling (July 1998) salinity at one meter below the surface was approximately 20% that of seawater at the Napa location, 30% at the Petaluma location, and 40% at the San Pablo Bay location.

Suspended sediment concentrations in San Pablo Bay during the 1998-year for example ranged from 30 to 91 mg / L. Suspended sediment concentrations in the Napa and Petaluma locations ranged from 109 to 113 mg / L and 190 to 370 mg / L respectively. High sediment concentrations in the river channels indicate that local re-suspension probably supplies sediment and sediment bound pollutants to the water column during tidal action in North Bay creeks and wetlands. It seemed likely that this would also occur in Sonoma Creek and indeed this is the case as shown by Warner et al. 1999).

Data from Warner et al. (1999) indicated a strong diurnal variation in sediment concentration in the sloughs of the Sonoma marsh. Sediment concentrations of up to 1,200 mg / L were measured over September 1997 to March 1998. At the mouth of Sonoma Creek, the range of concentrations did not appear to be different than concentrations during the fall and spring suggesting that sediment concentration is strongly controlled by tidal action in spite of pulses of freshwater at this site. Concentrations at Second Napa Slough reached 3,000 mg / L where as concentrations on Sonoma Creek above the confluence with Second Napa Slough only reached 1,000 mg / L. Third Napa Slough reach suspended sediment concentrations of 1,500 mg / L (Warner et al. 1999). This at least illustrates that sediment concentration is highly variable in the Sonoma Marsh system. Perhaps the variability is associated with the persistence of a local current velocity regime.

The USGS has been collecting salinity and water quality data in the North Bay since 1968. There are five sampling locations along the longitudinal gradient from the south entrance of San Pablo Bay to the mouth of the Napa River. This data could be used to help characterize water quality in San Pablo Bay in order to determine ambient conditions outside of the mouth of Sonoma Creek.

Sediment quality in the Sonoma Baylands

In August 1971, seven sediment core samples were taken from three locations within the Sonoma Baylands (USACE 1971). The locations were:

1. Highway 37 crossing
2. Highway crossing right bank
3. Confluence of Second Napa Slough and Sonoma Creek left bank

Samples were also taken from West Richmond Channel, and Napa River. No all samples were analyzed for all constituents but in general samples were analyzed for total solids, %moisture, volatile solids, C.O.D., Kjeldahl nitrogen, grease and oil, pH, lead, zinc, mercury, B.O.D., P.P-DDE, OP.DDT, Dieldrin, Arochlor 1254, BHC, Lindane, Heptachlor Like, TICH. At least 30% of the samples from the Sonoma Creek locations exceeded EPA guidelines. Excedences were for volatile solids, C.O.D., Kjeldahl nitrogen, grease and oil, and zinc. Sonoma Creek was the only location out the three sampled that exceeded EPA guidelines for grease and oil.

The USGS undertook a study in 1996 to investigate the occurrence, fate, and accumulation of organic contaminants in sediments and biota (Hostettler et al. 1996). This study was in conducted in relation to the reuse of dredge spoils from Petaluma for restoration work on the Sonoma Baylands. The compounds studied included aliphatic hydrocarbons (indicators or weathered or biodegraded petroleum), PAH’s and DDT, atomic C / N ratios which help to determine the source of sediment (marine or terrestrial), sterols (used to monitor wetlands after construction or disturbance as they revert back to a natural state). They concluded that Petaluma dredge spoils would only add trace amounts of contaminants to a wetland site.

Section 6
Watershed and Baylands Fauna

In-stream freshwater biota

Historical

Sonoma Ecology Center is beginning a historical ecology research project interviewing long-time residents and fishermen. A major topic will be historic fisheries conditions: locations, abundance, and species present. There is some question whether or not salmon were historically present in the watershed. Peter Moyle has stated that Coho were likely present; however, neither DFG records nor a 50-year review of the local newspaper's fishing and hunting column (Sonoma Index-Tribune fishing report, 1948-1990, compiled by Jordan Basileu) mention salmon. In 1965, it was reported that the annual steelhead run in Sonoma Creek was about 1,200 (Sonoma Valley Soil Conservation District 1965).

Contemporary

There are a number of key species of concern in or near the Sonoma Creek watershed that are listed either Federally or State listed. These include:

- California Freshwater shrimp (Syncaris pacifica) is a federally and state-listed endangered species.
- Winter-run Chinook Salmon (Oncorhynchus tshawytscha) is a federally and state-listed endangered species.
- Steelhead (Oncorhynchus gairdnerii) is federally listed as threatened.

In spring 2000 Sonoma Ecology Center began sampling benthic macro-invertebrates using the California EPA Stream Bio-assessment Procedure at twelve sites. This protocol is a simplified version of EPA's Rapid Bio-assessment Procedure. The protocol was adapted through field-testing by Sonoma Ecology Center staff and technical advisors. Joseph Brumbaugh, a locally knowledgeable invertebrate biologist, is assisting in developing macro-invertebrate key and tolerance categories and in training volunteers. SEC uses "D" frame kick-net samplers to obtain replicate samples from specific measured stream areas in a standardized fashion. From the replicate samples, a mean and variance can be calculated to estimate population size and variability. Samples are being identified to family taxonomic level at the SVWS laboratory. The samples are grouped into three pollution-tolerance categories and used to calculate a water-quality index. The results will be analyzed to draw conclusions about the biological health of the sampled sites.

Surveys completed by Larry Serpa (USFWS) found freshwater shrimp in many reaches of Sonoma Creek. Reports are available from USFWS and Sonoma County Transportation Agency, which commissioned recent surveys.

SEC has contracted with Entrix, Inc. to produce a scope of work for a steelhead population study. Available evidence suggests that this population is well below its historic level, but no comprehensive assessment has ever been performed in the Sonoma Creek watershed. A minimum of three years' monitoring work is necessary to adequately characterize the populations. Entrix is reviewing existing fisheries information and developing study design options and associated costs. Four Sonoma Ecology Center staff observed three Chinook salmon in lower Sonoma Creek in November 1998, one of which was an adult female on a redd. Robert A. Leidy conducted a number of fish surveys in the freshwater creeks and rivers of San Francisco Bay. The following summary (Table 5) is information directly extracted from the Leidy Fish database (Leidy 1999). SFEI has just completed the draft version of Leidy Fish online consisting of a clickable map interface. This can be viewed on the SFEI web page (www.sfei.org).

Chinese mitten crabs are an invasive species that affect watershed streams and the Baylands. These Crabs are common in other parts of the Bay and can be found in the middle reaches of creeks and regularly plug up the fish screens in the Delta. Sonoma Ecology Center maintains an informal record of sightings of Chinese mitten crabs, which have infested the waterways to some extent at least as far north as Agua Caliente. There have been no reports during the year 2000; possibly numbers are cyclic.

Table 5. The occurrence of fish species in freshwater areas of Sonoma Creek watershed, surveyed by Robert A. Leidy 1992 to 1998. Number represents individuals on a single sample date.

Species	No. of locations with fish	Total No. locations sampled	*Rainbow trout	*Riffle sculpin	*California roach	*Prickly sculpin	*Sacramento sucker	*Threespine stickleback	*Tule Perch	Bluegill	Western mosquito fish	*Pacific lamprey	*Sacramento squawfish
Bear Ck.	2	2	62	2									
Calabazas Ck.	6	7	84	39	36								
Carriger Ck.	1	1	5										
Graham Ck.	1	1	17	1									
Mill Ck.	1	1	7	1	2								
Sonoma Ck. Riverside drive at walnut av.	1	1		20	46		62	2					
Sonoma Ck. main road on state hospital	1	1	17	26	130		18						6
Sonoma Ck. 100m downstream from Madrone Road	1	1	2		239	31	17					3	2
Sonoma Ck. 50 m downstream from Harris Road Bridge	1	1	2		240	27	19	3					
Sonoma Ck. 20m downstream from Agua Caliente Bridge	1	1	3		49	25	22						1
Sonoma Ck. opposite stable parking lot in Sugarloaf Ridge state park	1	1	15										
Sonoma Ck. upstream of Hwy 121 crossing	1	1	2	8	13		8						4
Sonoma Ck. at 90-degree bend in Hwy 12	1	1			168	39	30	19					
Sonoma Ck. at Riverfront road	1	1	1	2	129	2	2	1	8		20		2
Sonoma Ck. upstream of Boyes Boulevard crossing	1	1	1		30	22	11			1			
Sonoma Ck. Adobe branch, Adobe Canyon, pool at the base of bedrock fall	1	1	7										
Sonoma Ck. Adobe branch, Adobe Canyon, upstream of bedrock fall	1	1	12	1									
Stewart Canyon Ck. 50m upstream of Trinity road	0	1											

* Native species

Freshwater fisheries habitat and spawning sites

General distribution of terrestrial vertebrates and Wildlife habitat maps can be queried from the GAPVEG coverage for general distribution of terrestrial vertebrates, but the information is coarse scale (>1:100,000 accuracy). SEC is conducting a habitat connectivity project that maps core habitats for barriers to movement of wide-ranging species and wildlife. This project will assist in identifying key connectivity zones and includes a regional habitat fragmentation analysis as well as a fine-scale evaluation of connectivity opportunities and barriers at the Sonoma Developmental Center property. Anecdotal information on the ability of fish or other wildlife to pass through various culverts, fences, levees, and sections of road is available from SEC.

SEC is conducting a pool habitat enhancement and restoration project, funded this year by CALFED. This will include a survey of approximately 30 miles of Sonoma Creek and its tributaries, following DFG methodology. The objectives are to quantify the amount, distribution, and functional characteristics of large woody debris (LWD) and estimate LWD recruitment potential. Stream reaches will be morphologically classified based on a Rosgen (1996) Level II inventory to aid selection of candidate sites for pool restoration. Sites best suited to provide steelhead rearing habitat and geomorphically suitable for restoration will be identified. Sites will be screened and ranked based on access, landowner interest and biological suitability.

The Northwest Emergency Assistance Program and Southern Sonoma County RCD conducted a fish habitat inventory from Madrone Road north in 1996 with training provided by DFG. This study quantified fish species distribution based on netting and visual observation, and recorded several fish habitat parameters. It provides a baseline for monitoring the status of fish in these important stream reaches. Sonoma Ecology Center have input the data and made it spatially more useable in GIS coverage. Sonoma Ecology Center conducted a study on eight potential spawning locations. Replicate gravel samples were taken in 1999 using a McNeil sampler following a protocol adapted from Matt Kondolf. All of the sample sites were suitable for steelhead spawning. The study concluded that there are appropriate spawning sites in the watershed, although their number may be lower than necessary to support an optimal steelhead population.

Estuarine biota spatial extent

Large populations of the sand clam (Macoma nasuta) and the Bay mussel (Mytilus edulis) abound in the sloughs and mudflats between San Pablo Bay and the Second Napa Slough. Eastern soft shell clams (Mya arenaria) are present at the mouth of Sonoma Creek (USACE 1972). Salt marsh harvest mouse are known to inhabit are areas east and west adjacent to the mouth of Sonoma Creek and near the mouth of Tolay Creek (Newcomer 1982; LES & WRA 1992). According to the Goals Project Focus Team Support Map, much of the Sonoma Marsh system is either suitable or formally suitable habitat for salt marsh harvest mouse. The Suisun shrew once inhabited the lower Sonoma Creek on the southern portion of Skaggs Island and south to the Bay edge and the mouth of Sonoma Creek (Rudd 1955). A later survey by Williams (1983) failed to trap any specimens perhaps because they are so difficult to trap. According to the Goals Project Focus Team Support Map it seems that there is still some confirmed presence in these areas adjacent to the Bay.

Leidy (1999) recorded a number of fish species and individuals in many locations of the Baylands of San Francisco Bay. The following summary was constructed using information directly from the "Leidy Fish data base" (Table 6). The relatively few species and numbers found in this study may reflect the difficulty in counting that is associated with tidal saline channels and highly motile species. It may also reflect a system under stress.

Table 6. Occurrence of fish in tidal areas of the Sonoma Creek watershed recorded by Robert A. Leidy surveys between 1992 and 1998. Number represents individuals on a single sample date.

Location	Striped Bass	Yellowfin goby	*Prickly sculpin	*Tule Perch	*Longjaw mudsucker	Chameleon goby
Second Napa Slough		4				
Third Napa Slough	3	2				
Steamboat Slough	35	1		1	1	1
Sonoma Ck. from mouth upstream to Second Napa Slough			4			

* Native species

Bird life, temporal and spatial extent

Historical

Sonoma Creek flows into the area of the North Bay designated as the San Pablo Bay Nation Wildlife Refuge. This area is a major refuge for many species of birds that include migratory birds of the Pacific flyway, waders, and predatory species. There are few records of the exact historical distribution or abundance of the Sonoma Marsh fish or wild life. There is currently no systematically compiled information that can determine how many of a certain bird species there used to be, or, for example, whether rare plants were always rare. The best information of the historic abundance and distribution of birds species stems from inference of the kinds of habitat requirements of particular species and therefore from maps of historical habitat distribution. It is recommended that an historical ecology project be initiated to determine historical types and abundances of native species as a tool for setting or refining goals for Marsh restoration.

Contemporary

Although many species have been reduced in numbers, the good news is that there are still known occurrences of some key species in the lower Sonoma (Goals Project 1999). California clapper rails inhabit the saline and brackish-saline tidal marsh of the lower Sonoma. They are found at the mouth on San Pablo Bay, on the Napa Slough, around the confluence of the Second and Third Napa Sloughs. California clapper rail are also found in the Napa / Sonoma Marshes wild life area at the north end of the Third Napa Slough (Gill 1979; Hobson et al. 1986; CDFG 1977B). Steamboat Slough Marsh, a 256 acre tidal Marsh, supports the densest population of California clapper rails in the Napa / Sonoma Marsh lands (CDFG 1977A).

Western sandpipers, marbled godwits, and long-billed dowitchers are migratory shore birds that use the North Baylands for resting and feeding, however none of these species are presently listed as threatened. The high use area runs from Petaluma to the eastern edge of the Napa-Sonoma Baylands. The USGS and the U.S. Fish and Wildlife Service have surveyed the northern pintail, both in the air and on ground. They are found in many locations in the Petaluma, Sonoma and Napa Baylands (Goals Project 1999). Black rails have been observed at the mouth of Sonoma Creek and east along the southern edge of Skaggs Island (Evans et al. 1986; 1988). The salt marsh yellow throat inhabits most of the sloughs and Sonoma Creek downstream of Schellville (Hobson et al. 1986). The San Pablo song sparrow inhabits the brackish marshes along Sonoma Creek (Marshall 1948; Walton 1975). Lower Tubbs Island preserve features an outstanding variety of wildlife and habitat that includes California clapper rail, salt marsh harvest mouse, burrowing owls, white tailed kites, and harbor seals (CDFG 1977A).

Section 7.

Causes of flooding

Introduction

Flooding has been occurring in the Sonoma Watershed and Baylands during the whole period of European occupation. What is uncertain is how much flooding character has changed over time and what were the primary causes for changes. Nichols (1956) describes the character and causes of flood inundation during the 1955 / 56 winter floods. A large fan developed in the creek bed north of Hwy 12. This fan caused water to flow through an overflow channel that soon eroded into a wide streambed and formed a new channel. On the tributary of Sonoma Creek that crosses Sonoma Hwy about 1/5th of a mile east of Kearn Road, the channel filled completely with large stones so that floodwaters spread out over neighboring properties. The stream between Riverside Bridge and Schellville has a slope of 3 feet per 1000 feet, but as it enters the delta the slope changes to 3 feet per mile. Here the cross section decreases and floodwaters top the banks and erode banks and levees. In the lower watershed banks can stand vertical for 10 to 12 feet but due to a lack of cohesive material in the soils, when flood water impinge upon banks due to the meandering nature of the creeks, erosion occurs rapidly within hours (Nichols 1956).

The 1965 report indicated that the major flood problems in the Sonoma Basin arise from inadequate channel sections, unstable levee section adjacent to some of the channels, and inadequate openings under highway and railroad bridges. These features combined with the tidal action have resulted in flooding below state highway 37 (Anon. 1965). Another report written about the same time also suggested that silt and debris that deposit in the lower channels and high tides during floods also play a major role in increasing flood damage in the lower Sonoma Valley (Sonoma Valley Soil Conservation District 1965).

Hypotheses

The following are plausible hypotheses that may contribute to flooding in the lower Sonoma Watershed and Baylands. These should serve as a starting point for any future investigations.

1. *Flooding in low gradient tidal floodplains is a natural phenomenon typical of a narrow valley. The frequency and magnitude of flooding in the Sonoma Valley has not changed significantly in relation to European inhabitancy*
2. *Flooding is caused by changes in the flood hydrograph (higher flood stage, shorter time of concentration, greater total flood volume) associated with urban and rural development in upstream areas. Everybody over the years has done their little thing to stop flooding in their local area. This has forced water to a different spot downstream. As soon as you get people in a watershed, there is allot of changes because nobody wants the floodwater*
3. *Flooding is caused by loss of channel capacity at Schellville because channel aggradations have occurred*
4. *Flooding is caused by the channel being narrowed by human modification upstream and / or near Schellville*
5. *The highway 121 Road Bridge restricts flow causing flooding*
6. *Flooding is caused by more snags in the river that reduce capacity such as engineering structures or fallen trees associated with bank erosion*
7. *Flooding at Schellville is caused by water backing up due loss of channel capacity in the tidal areas between Schellville and San Pablo Bay due to land-use change, drainage, and levee construction and associated reduction in the tidal prism. This would cause the system to adjust to lower velocities and tidal water volume exchange by channel sedimentation and / or narrowing*
8. *Flooding is caused by loss of channel capacity and the loss of the dispersive floodplain caused by land-use changes and levees alone*
9. *Sea level rise*
10. *An increase in the tidal range*
11. *Flood damage is caused by the fact that people have historically built their houses and their roads and their fire station in the wrong place (the floodplain)*
12. *The historic flood bypass areas have filled with sediment making them less effective at transmitting water. Historically, Sonoma Creek used to be the greatest concern to residents in the lower watershed but now the water bypasses to Second and Third Napa Sloughs. The "elevation in water" has switched from one side to the other. It is suggested*

that levees may have been part of the cause, ponding water and allowing sediment to settle out

13. *Flooding from Sonoma Creek is caused by Sonoma flow being impeded by flow from Fowler Creek. Fowler Creek, upstream, has been developed recently more intensively. There is probably more runoff from Fowler Creek than ever before*
14. *Flooding in the Schellville are has worsened because routing of waters through the watershed have been altered. Aerial photos from the 1940's show the streams from the western side of the watershed entering Sonoma Creek at three locations. Today they all join Fowler creek and enter Sonoma Creek at Schellville. This would effectively concentrate all the flow, increasing the peak flood height and reducing the width of the hydrograph*
15. *Flooding problems around Schellville are associated with the railroad levee*
16. *Flooding is caused by a combination of many factors (all / some of the above)*

Section 8.

Restoration projects: Historical and contemporary

Review of the history of mitigation options

The following brief summary of some of the alternatives for the alleviation of flooding in the lower Sonoma Creek watershed that have been proposed in the past (Table 7). It is not intended to prescribe options that would be suitable for consideration in the present economic, environmental, engineering, political, social, and scientific climates, but it does serve as testimony for the immense amount of thinking and money that have already been directed at the problem.

Table 7. A history of the options and recommendations for dealing with flooding issues in the lower Sonoma Creek watershed

Year	Reference	Page	Options / Recommendations
1939	1		Recommendations
			"The district engineer finds that the damages caused by floods in Sonoma Creek, California, are minor in amount and that the improvements of the of the stream for flood control is not justified. He recommends therefore, that a survey for flood control be not authorized"
1956	2		Options
			1. Progressive construction of bank protection and straightening 2. A floodway through to San Pablo Bay with width and levee height suitable for carrying floodwaters with danger of inundating valuable adjacent lands 3. Dam on Nathanson Creek at Alta Vista (about 1 / 3rd of the areas of Sonoma Creek
			Recommendations
			1. Channel enlargements, straightening, and the construction of additional levees. Due to rising populations, the flood control problem will be come worse over time 2. The waterway under Hwy 12 Bridge should be cleared and the channel downstream widened and straightened
1965	3	23	Options
			1. Reservoirs for flood control 2. The construction of cutoffs 3. The diversion of flows through Napa Slough 4. The diversion of flows through Schell, Steamboat, and Napa Sloughs
			Recommendation
			1. Alignment and trapezoidal shaped channel enlargement of the Sonoma Creek channel for 15 miles to Boyes Springs Road, construction or improvement of levees through the delta area, increasing the capacity under bridges, providing bank protection where required (riprap 12-15 inches thick over a 6 inch filter blanket), providing the related interior drainage facilities, and providing recreational facilities in areas adjacent to the proposed channel improvements

Table 7. Continues

Year	Reference	Page	Options / Recommendations
1972	4	4	Options
			Baylands reaches 1. Channel dredging and improvement of existing levee from the Bay to Hwy 121. Bottom widths would be 320 to 440 feet in the area between the Bay and Second Napa Slough and width of 190 to 320 would be maintained between Second Napa and Hwy 121. Alignment would be similar to existing plan view. This would result in the loss of some salt-water marsh and benthic populations, temporary disruption of the food chain, and the potential introduction of pollutants from the spoils (mud exceeds EPA guidelines for grease and oils, nitrogen and volatile solids). Fish and wildlife including sand clam, Bay mussel, and eastern soft-shelled clams would be displaced by construction and turbidity brought about be dredging. Loss of a strip of cord grass by change in water elevation 2. Replacement of existing levees on one side of the creek and construction of new levees set back father from the stream. This plan eliminates the need for channel dredging and provides the required channel capacity. There would be some modification and displacement of wildlife areas adjacent to the channels 3. Floodplain zoning and management 4. Permanent evacuation in the reach between the Bay and Second Napa Slough by purchase of all the land within the floodplain
			Areas in the vicinity of Schellville 1. A rip rapped trapezoidal channel closely following the present channel alignment with bottom widths of 45 to 55 feet. Loss of the aesthetic value and natural stream setting, loss of some wildlife, and habitat, and temporary loss of benthic organisms 2. A low velocity Fowler Creek diversion with a 1,000-foot floodway protected with low levees following the generally following the alignment of Fowler Creek. Diversion would occur just below West Napa Street and would re-enter at the confluence of Sonoma and Fowler just north of Hwy 121. This option would preserve Sonoma Creek but result in the loss of vegetation and wildlife habitat during construction on Fowler which would be replaced by natural process and plantings 3. A high velocity Fowler Creek diversion with a rip rapped 40 to 60 foot excavated channel following the existing Fowler Creek alignment. Preservation of Sonoma Creek at the cost of aquatic organisms and wildlife habitat in Fowler Creek 4. Construction of offset levees approximately 600 feet apart. The natural stream setting along Sonoma Creek would be preserved although there would be some loss of wildlife and habitat associated with levee construction and continuing sediment erosion on the creak banks Floodplain zoning and management

[1] USACE 1939

[2] Nichols 1956

[3] Anon. 1965, USACE 1963

[4] USACE 1972

Sonoma Ecology Center restoration projects

Introduction

Sonoma Ecology Center has already actively begun many of the types of watershed-wide measures that will help to alleviate flooding and improve environmental quality. Many of the restorative actions SEC have conducted, and that are envisioned in the future, differ from classical restoration, which is often limited to “moving dirt and planting trees.” Other approaches may be at least as effective in Sonoma Valley such as education of residents, policy-makers, and landowners; presenting sound information on how human practices affect the landscape; and pursuing innovative policy and habitat preservation alternatives. The reason for including these approaches in restoration planning is that land in the Sonoma Creek watershed is mostly privately owned and very expensive. Outright purchase of land as a means of habitat protection or restoration is not always feasible. To purchase a riparian area of a few hundred acres can be more expensive than a large-scale flood control project. For this reason, other preservation options are usually needed, such as education, landowner participation in voluntary setbacks or a lower-cost easement. In the Sonoma Creek Watershed, as in other Bay Area watersheds, restoration plan design is as much about property owners and their heirs, real estate issues, and County politics as it is about water levels, hydrologic modeling, and planting plans. With this context in mind, following is a catalog of SEC’s restorative projects.

Past and current SEC projects

Past and current projects watershed-wide include:

A. Pool habitat enhancement and restoration. A currently funded DFG grant will survey large woody debris conditions in the watershed, select high-priority sites for LWD installation, design site-specific pool enhancement measures, implement them, and monitor their success

B. SEC’s Restoration Project conducts community-supported work-days to stabilize stream banks, clean garbage from creeks, replant native vegetation, and remove invasive species such as Arundo. SEC also provides technical assistance for residents, including riparian and vineyard landowners, who are interested in restoration or improving land-use practices

C. SEC has mapped most of the *Arundo donax* infestations in the watershed and conducted successful eradication efforts with volunteer labor at a handful of sites. SEC is administrating a large CALFED grant for Team Arundo del Norte, which includes funding for eradicating most of the riparian Arundo in the watershed above the Highway 121 Bridge. Eradication will begin in fall 2001, again utilizing significant volunteer contributions of labor, working from the top of the watershed down

D. SEC's many education-oriented projects work to change the day-to-day practices of all watershed residents. While education may seem remote from actual habitat protection, a better-informed watershed population can result in, for example, a vote to continue substantial funding for the Sonoma County Agricultural Preservation and Open Space District, or neighbors who encourage a landowner to allow restoration or an easement on their property. SEC's education activities include a quarterly newsletter, a twice-monthly natural history column and regular feature articles in the local newspaper, frequent informational talks to homeowner groups, teachers, and other interested groups, bringing experts to speak to the community through Watershed Council meetings, support for agency and government staff, informational stenciling of storm drains, workshops for riparian landowners leading to fish habitat restoration sites, dialog with land-user groups such as the Sonoma Valley Vintners and Growers Alliance, and expert commentary at public discussions of natural resource issues. Every other year, the Sonoma Creek Watershed Conservancy sponsors Sonoma Creek Day to celebrate the creek and share watershed data with the community

E. SEC participates in regional forums that guide and prioritize restoration funding; e.g. San Francisco Bay Joint Venture, Watershed Workgroups of CALFED and California Biodiversity Council

F. Funds have been secured to design and implement a solution to a steelhead barrier under Arnold Drive at Asbury Creek near Glen Ellen. Construction will proceed in summer 2001

G. Nathanson Creek Preserve Project: a ¾ mile long riparian corridor preserve along Nathanson Creek through the southeast region of the City of Sonoma, including Sonoma Valley High School. The project envisions a restored riparian habitat zone along the length of the project area, including facilities for research and education. It will be a model project for creek restoration in the valley. Partners include the City of Sonoma, the Sonoma Valley Chamber of Commerce, SEC and other groups and individuals. Sonoma County Agricultural and Open Space District has committed funds for land acquisition, and state funds have been committed for a bike path; funds are needed for a restoration plan document and implementation

H. When floodwater eroded a section of stream-bank on Sonoma Creek near Madrone Road, SEC staff met with individual neighbors and encouraged them to coordinate their concerns and work together to seek emergency assistance. Eventually, the homeowners obtained funding through NRCS and the SSCRCD for a coordinated bank stabilization project that had both economic and environmental benefits

I. Van Hoosear Wildflower Preserve is a private site along a tributary to Carriger Creek. Over many years, SEC has worked with several organizations on projects there such as native seed collection, riparian re-vegetation, stream-bank stabilization, and riparian fencing. The stream, denuded and dry for many years, is now re-vegetating, flows are returning, and steelhead have been observed in the stream. Sixty school children have invested work at the site, and the Sonoma County Agricultural Preservation and Open Space District is considering an easement to protect it

J. Stream-bank stabilization projects on Sonoma Creek near Glen Ellen, each between approximately 300 to 800 feet of stream. Two sites were completed in 1997 and 1998, and one is planned for 2000. All three sites used or will use bio-technical approaches, native re-vegetation, and / or gabion baskets

K. SEC is working on an ambitious habitat preservation project that would protect the natural resource values of several large parcels that span the entire valley from Sonoma Mountain to the Mayacamas range. The Sonoma Valley Habitat Corridor lands, totaling approximately 2400 acres, are in public ownership and in private easements. Their protection represents a unique chance to preserve habitat connectivity in the North Bay

L. SEC collaborates with the SSCRCD and Sonoma Valley Vintners and Growers Alliance in several restoration projects, through the Sonoma Creek Watershed Conservancy

Future SEC projects

These projects are organized by topic for watershed-wide projects and by geography for site-specific projects.

A. A feasibility study for developing and maintaining a sustainable self-sufficient water supply, probably relying heavily on conservation, re-use, and rainwater collection

B. An ongoing, permanently funded program to monitor water quality, quantity, uses, sources, and sinks. To identify problems, it is necessary to know what the background variation is. Water data should be taken in combination with data on neighboring and upstream land-use practices and width of undisturbed riparian areas

C. Repeat the SEC campaign to stencil bilingual warnings on storm drains in residential areas in Sonoma, El Verano, Boyes Hot Springs, Fetters Hot Springs, and Agua Caliente

D. Put eroding back-country roads to bed where owners are willing by building on existing projects to retire roads in Annadel State Park, SEC would like to address Jack London and Sugarloaf State Parks, two large headwaters areas with badly eroding roads and trails

E. Select and fund site-specific projects to conserve water, water quality, and topsoil at vineyards and related facilities. A panel of Sonoma Valley Vintners and Growers Alliance, SSCRCD, and SEC reviewers choose projects to fund; SEC, SSCRCD, and landowners monitor project success

F. Establish a riparian land trust, the Sonoma Valley Creeks Trust, for obtaining fee title and / or easements of creek channels, creek banks, riparian setbacks, associated wetlands and recharge lands. Rationale: The anadromous fishery of the Sonoma Valley Watershed is largely dependent on the health of the riparian corridors. The riparian corridors are owned by hundreds of separate private property owners, and many government entities. If a long-term plan for obtaining private riparian land by purchase or gifting were set up, the resulting protected areas would become permanent restoration sites and would be removed from development stress. Over decades a substantial portion of the riparian lands could come under protection, thus heightening the possibility of completely reestablishing the anadromous fishery. Correspondingly, agreement by government entities to adopt restrictive easements on government-owned riparian lands would ensure long term plans for restoration can be undertaken

G. Enforce existing stream setback mandates in Sonoma City and County General Plans

H. Develop a Riparian Master Plan. The Plan would integrate a number of types of information and recommendations, including assessment of current conditions, comparison with historic extent and condition, management recommendations to cover issues such as pollution abatement, wildlife and plant habitat, habitat connectivity, water quality and quantity, supply of large woody debris, recreation, flood control, and erosion prevention

I. Oversee a long-term program of controlled burning on public wild-lands and among groups of willing landowners, to stimulate biodiversity and reduce risk of catastrophic fire

J. Demonstrations and workshops at nurseries and garden clubs to encourage native landscaping and educate people about invasive plants. Create a native plant nursery for landscaping and restoration. Form a Weed Management Area for the North Bay or similar area. Pay a full-time invasive plant coordinator for the Sonoma region. Focus on Arundo, yellow starthistle, broom, tree of heaven, acacia, and eucalyptus

K. The Sonoma Creek Watershed Enhancement Plan, 1997 (prepared by the Southern Sonoma County RCD) found that pool habitat (probably due to lack of large woody debris) is lacking in the watershed. SEC now has funding to design and implement restoration actions at 12 sites to increase the frequency and quality of pool habitat for steelhead trout and freshwater shrimp. Restoration designs will emulate natural channel hydraulic processes whereby large woody debris (LWD) provides scour to create and maintain pools. LWD placement will provide hydraulic diversity and cover to improve rearing conditions. Tasks will be supervised and conducted by a geomorphologist, riparian specialist, and / or fisheries biologist, with assistance from interns and Stream Stewards. SEC will assess baseline conditions before LWD installation. Funding is needed for post-project monitoring. Follow-up monitoring of these projects is essential. Besides ascertaining the projects' success, assessment of their long-term effects is important to address landowner concerns about flooding and bank erosion. Monitoring will consist of cross-sectional surveys during the low flow season, photo-documentation, fish utilization surveys (with snorkeling or electro-fishing), and monitoring reference pool sites

L. In Kenwood, Sonoma Creek is actively eroding its stream-bank, threatening to undermine Warm Springs Road. A large pool that provides rearing habitat for steelhead is immediately adjacent to the erosion site. Spawning has been observed at the pool tail-out. Without pro-active management it is likely that the unstable bank will fail during a flood event, collapsing the roadway and causing rubble and fine sediments to enter the pool and spawning area. Repair of the stream-bank and roadway under emergency action will not allow time to plan measures to provide vegetative or in-stream cover, or to protect rearing and spawning habitat. SEC will develop a design to prevent bank failure, protect Warm Springs Road, and maintain and enhance cover elements associated with aquatic habitat. Design drawings will include material and construction specifications suitable for implementation and permitting. SEC will coordinate the project with California Department of Fish and Game (CDFG), Sonoma County Permit and Resource Management Department, County Public Works, and National Marine Fisheries Service. It is anticipated that the County will fund implementation, and SEC will monitor project success using future funds

M. SEC's studies indicate that, although the supply of suitable spawning gravels appears to be sufficient, there are limited sites for deposition of these gravels. Funds are needed to undertake the studies to prepare channel designs, which would increase opportunities for spawning gravel deposition. In addition, using the channel restoration / enhancement design at a site-specific location, a pilot project would be implemented to create spawning habitat

N. Over time, modify or replace culverts, bridges and other infrastructure that inhibit wildlife (including fish) movement. Implement recommendations of proposed study on habitat fragmentation infrastructure, including installing under-crossings, purchasing easements, or other actions

O. Develop eco-tourism in Sonoma Valley, as a way to preserve undeveloped land by making its economic value competitive with other land-uses. Meet with Visitor's Bureau and Chamber of Commerce. Possible activities for eco-tourists include hiking, wildlife viewing, edible plant gathering, hunting, fishing, gathering acorns, photography, painting, diverse small-scale U-pick agriculture, olives, basketry, making wine

P. Put on a workshop for focusing on construction, maintenance, retirement, and environmental impacts of backcountry roads. Participants might include fire agencies, agriculture representatives, homebuilders, State Parks, Sonoma Developmental Center, transportation agencies. This was a great success in the East Bay

Q. Design and present workshops for local landowners and citizen groups on existing regulations that protect riparian and aquatic habitat. These include stream setbacks, erosion and pollution controls and practices that minimize common ecological problems arising from dominant land-uses (e.g., vineyard, residential, dairy). SEC will review local zoning ordinances, general plans, state and federal regulations and other government documents relevant to land-use. The workshops will convey the biological or geophysical basis for existing regulations and communicate the intent of the regulations beyond the letter of the law. SEC will present at least two workshops.

R. Workshops for government staff on importance of existing environmental regulations and guidelines, focusing on stream protection and soil conservation. Develop cooperative agreements with agencies, through Watershed Station, to take on tasks that they lack the staff to accomplish. Through these agreements, SEC would be providing services that should be as accepted as patching roads. If a healthy watershed is a goal, some oversight will be required for certain maintenance, monitoring, restoration, and planning functions.

- Disseminating advice and information to public, landowners, and local government staff. Share and receive information and lessons to / from other places and processes
- Monitoring, tracking conditions, analysis, reporting to community
- Restoration opportunities, vulnerable places, working with partners for implementation or protection
- Keystone processes (habitat connectivity, fire, floodplain dynamics) or species (salmonids, mountain lions, native grasses) or places (core habitats, riparian areas, wetlands)
- Choose and apply an index of ecological health
- Conducting restoration that is planned in a long-term, watershed context, not just quick fixes
- Planning for sustainability, generating good ideas for the future
- Expert commentary on proposed development documents or at public discussions, maintaining a presence in the public decision-making process to improve the factual basis of discussions, bring ecological issues into discussion
- Encourage collaborative, inclusive, creative community decision-making. Provide facilitation / mediation services, emphasize to stakeholders the benefits of working collaboratively

S. Facilitate a watershed-wide community discussion of desired future conditions and submit recommendations to the County. The first step would be to negotiate an agreement with County to use these recommendations when updating the General Plan. Project would include meetings with, and guidance from, individual planners at the County. Possibly strengthen the autonomy of Area 9, the Planning Area that covers Sonoma Valley

T. Develop a regional GIS tool allowing comparison of economic and ecological values of development versus conservation / restoration on a particular piece of land. This decision-making tool would show the economic value of ecosystem services, including classic environmental benefits such as water supply and water quality protection, as well as tourism, scenic contribution, education, health benefits, etc.

Options or issues in relation to habitat restoration in the lower Sonoma Creek watershed

The overall goal for the North Bay is to restore large areas of tidal marsh and to enhance seasonal wetlands (Goals Project 1999):

1. Tributary streams and riparian vegetation should be protected and enhanced and shallow sub-tidal habitats should be preserved or restored
2. Tidal marsh restoration should occur in a band along the Bay Shore and up into the watershed of the major rivers, including Sonoma Creek
3. Seasonal wetland should be improved in areas that are currently agricultural
4. All remaining seasonal wetlands in the uplands adjacent to the Bayland should be protected and enhanced

The goals project recognized that achieving many of these goals is going to depend on the agricultural sector.

The following is a personal communication from Peter Baye at the Fish and Wildlife Service (USFWS). It may not necessarily reflect the USFWS stance as a whole but it certainly illustrates some of the issues that he and others there are discussing in relation to rehabilitation of Skaggs Island at the time of writing this current report. Things that warrant consideration and priority include:

1. The persistence of widespread relict prehistoric tidal slough depressions, which may be restored or enhanced (exaggerated relief, cross ditches in-filled or blocked, channels severed by cross-dikes reconnected) to provide a genuinely restored tidal channel system

2. The proximity abundant tidal sediment supplies and relatively saline brackish marsh influence from the mouth of Sonoma Creek

3. The potential for minimizing flood-protected perimeter by acquiring adjacent subsided Baylands, rather than adopting a less cost-effective construction approach to flood protection.

There is an inherent potential for restoring a large, un-fragmented tidal marsh system with minimal edge along conflicting land-uses. This is emphasized because of one of the principal inherent restoration assets of Skaggs Island, the restorable relict slough topography, would be forfeited if dredged material were applied generally, as at Sonoma Baylands (which, by contrast, retained minimal relict slough topography). Also, a large proportion of project funds may have to be allocated to flood protection construction work unless protection needs are minimized by strategic acquisition / easement of adjacent parcels (Rainbow Slough / Haire).

Skaggs is subsided, but only a couple of feet lower than pond 2A (550 acres), which underwent remarkably rapid sedimentation following and undersized breach and sub-optimal (but un-engineered) restoration conditions. There is great opportunity at Skaggs to test the efficacy of tidal restoration of a moderately subsided Bayland parcel at a large scale with minimal engineering. It would provide a contrast with Cullinan Ranch, which has a 3-mile highway "edge" needing flood protection, and tidal sources remote from the San Pablo Bay mudflat reservoir of sediment.

Schellville contains alluvial soils near the historic salt marsh / lowland ecotone, which is essentially extirpated in northern San Pablo Bay. Though there is relatively lower potential for endangered species habitat restoration here compared with Skaggs, there is potential to restore relatively planar grassland / foreland communities intermediate between vernal pool / swale, tidal marsh pan, and tidal brackish marsh, as well as tidal marsh / riparian ecotones which could support the rare Aster lentus at the probable type locality of "Aster sonomensis" (Sonoma aster, placed in synonymy with A. lentus, Suisun Marsh aster).

The following are thoughts from SEC on issues in relation to the Baylands of Sonoma Creek. In the early 1990's, the Department of Navy ceased its communications operations at Skaggs Island. The area contains several acres of buildings, and several hundred acres of undeveloped open land. Due to a lack of natural sediment deposition, dewatering, oxidation of organic marsh soils, and possible fault block subsidence, most of the area is now several feet below sea level and pumps must run in order to keep Bay water from encroaching throughout the island.

Considerations:

1. Restoration of tidal marsh is probably feasible, and ecologically desirable; however, nearby landowners would likely need to have additional levee construction or, if they are willing, fair compensation for property or for property damage that may occur during high water events. If acquisition of property is a preferred option, it is important to frame the expenditure within the goals of the larger project. Acquisition can be costly in this region, and local landowners have at times been approached for land acquisition with offers that are less than fair market, creating a sense of mistrust and a loss of cooperation

2. The facilities section of the former base consists of several habitable and unusable structures and housing units. No weapons or industry of any scale were used at the facility, so the site is relatively clean. A number of state and local interests through the Skaggs Island Foundation made a series of attempts to obtain the facilities for an educational, live / work campus, based on a series of military base conversion models, such as Fort Mason in San Francisco. The remainder of the property was to be obtained by USFWS for restoration and addition to the San Pablo Bay National Wildlife Refuge. The agency responsible for dispensation of the facilities moved too slowly for that group of interests, and it is SEC's understanding that the future of the facilities area is still uncertain

Specific research objectives that should be considered for the possibility of habitat restoration include:

a. Effects to associated wetland habitats and T&E species
b. Changes in sediment supply and hydrology

c. Costs / options for maintenance of facilities grounds and other properties below sea level
d. Impacts to adjacent landowners from various options
e. Cost / benefit of facilities reuse versus deconstruction and debris removal

3. Hunting and duck clubs are common in the Baylands. Their management priorities are not always consistent with maximizing biodiversity and natural wetland functions. There may be management changes at the clubs that could better maximize these functions. If a consortium or forum of these clubs was formed that included other wetlands interests, creative ways to meet the interests of the club users and still benefit wildlife and wetlands could be developed

4. An analysis of the benefits and disadvantages of expanded eco-tourism in the Baylands (canoeing, wildlife viewing, etc) would be helpful for land-use planning in that area

5. It would be useful to assess the water quality and wetland impacts of the many new vineyards in the Carneros region. Most of these vineyards drain to small waterways, so their impacts, if significant, are more difficult to assess. The Sonoma Creek Watershed has historically seen several waves of agricultural uses whose impacts are cumulative both downstream and over time

6. There is a source of fresh treated wastewater at the Sonoma Valley Sanitation District in the lower watershed. Currently this water is being used for agricultural irrigation in the lower watershed, but it could be used for restoration. For example, there have been discussions about using treated wastewater to dilute water in salt ponds. Other possible beneficial uses might include groundwater recharge, for example to make up for groundwater withdrawals around the golf course. SEC's current contract with SCWA will examine possible uses of reclaimed water and possible conflicts with groundwater recharge. A larger scale quantitative analysis would be useful

7. Wetlands at Viansa, currently being maintained as freshwater habitat, could be expanded. It would be useful to compare the benefits of those wetlands being fresh versus saline

8. The railroad presently creates a hydrological and biological barrier. Some suggest that the hydrologic problems around Schellville began when the railroad was built. Should the railroad be revived for transport, commuter and / or tourist? What would the economic and environmental impacts be of a new station at Schellville, and the effects of increased tourism in that area? Should the levee for the old railroad spur, now breached, be removed entirely for habitat and hydrologic reasons?

9. Acquisition or protection projects should emphasize sites that provide connectivity between habitat types, especially between wetland or riparian habitat and adjacent upland habitat (as stated in the San Francisco Estuary Project's Goals report for Baylands Habitat). Examples are present between Sears Point and Viansa.

Section 9.

Guiding Principles for successful flood control and restoration

Strong community involvement

Any project that is developed to try to reduce flooding in the Sonoma Creek watershed will need to have strong community involvement from the first stages of conception through to design and review stages and post-implementation monitoring. The community is deeply invested socially and financially in the watershed and has many concerns associated with the management of the watershed either as a whole or in local portions of it. The public holds a lot of anecdotal knowledge gathered, sometimes unknowingly, collectively from generations of observing and living within the Sonoma Creek watershed environment. The community has watched all the changes and in many cases monitored the changes associated with their own specific interactions or modifications of sections of the watershed or stream channel.

At the August 30th technical advisory meeting, lengthy discussions with three local residents in the lower Sonoma Creek watershed area and representatives from San Francisco Estuary Institute (SFEI), Sonoma Ecology Center, the Southern Sonoma County Resource Conservation District, San Francisco Regional Water Quality Control Board, the Coastal Conservancy, the Army Corps of Engineers, and the U.S. Fish and Wildlife Service, helped to determine a range of community concerns and questions on the minds and mouths of residents. To an extent, these public concerns also include issues raised with Paul Sheffer and Karen Rippey at five previous public meetings. The following list should be treated as a starting point rather than totally reflective of a true cross-section off community feelings:

1. Floodwater comes over our levee
2. Floodwater comes over our road
3. Floodwater flows out of a localized watershed channel rather than from the upper watershed and causes inundation and damage
4. Floodwater flows into our garage or basement
5. When floodwaters cut of the roads, fire engines cannot react to emergencies
6. My crops are ruined by flooding
7. Erosion on the creek edges removes some of my property reducing the value of my land

8. Meetings held during the daytime that discuss flooding and other watershed issues are difficult for me, a resident, and landowners to attend because of our daily schedules
9. A flood control project that includes restoration of the Baylands and excludes channel modifications will not be effective in reducing the effects of flood damage on me or my property
10. Water backs up in the area above the fire station and cases flooding on my property
11. I think that land-use management questions are not being addressed adequately by the County or City
12. Goals set on a broad basis, such as the Goals Project (1999), will lead to large scale acquisition of mine and my neighbors land so that it can be flooded for flood control and wetland restoration
13. I may be underpaid for my land in the event of being forced to sell rather than being given the choice. If a flood project goes ahead, "you" shall not rob us of our land values without paying us compensation
14. We, the community will be given limited opportunity for input and discussion on water issues
15. What effects will future land-use changes have on flooding on my property
16. What effects will future land-use changes have on the availability of ground and surface water for consumption and irrigation of my land during the summer months
17. Flood restoration may change my lifestyle or that of other local residents
18. Why should my tax dollars be used to pay for flood control when I own a property outside of the flood plain that doesn't flood
19. I think that some parts of the community may be getting more than their share of water during the summer (for instance the vineyards)
20. Why should a flood control project go ahead when it benefits only a few member of the community in the lower watershed
21. Revetments, channelization and levees in the middle and upper watershed increase the amount of floodwaters that flow onto my property in the lower watershed
22. A flood control project that does not channel the water out to the Bay will just transfer the problems from one landowner or resident to another. I think that is unfair and if it happens there should be adequate compensation for the people newly effected

23. If you change the system you will have to prove to me that my levee will continue to protect me from floods like it used to
24. A flood control project that allows water to pool in the tidal areas of the lower watershed may cause damage to my property
25. I fear that if many public meetings are held, the public attending one meeting will get told something different to the public attending a meeting with the same objectives the next day
26. I fear that even if lots of scientific studies go ahead, like on all occasions in the past, the idea of flood restoration will all be dropped in a few years and nothing will happen to change the flooding problem
27. I live in the flood-prone area and I think that if we involve everyone from all areas of the watershed, we will be out voted because the people who aren't flood-prone wont want to spend a dime on saving a "few farmer peasants downstream"

Clearly any projects initiated to help reduce flooding in the watershed will need to involve a strong public consultation process.

Historical Landscape Ecology

What was the character of the historic system and how did we got to where we are today?

To understand current conditions in the Baylands and watershed of Sonoma Creek, and to develop restoration and management plans which are likely to succeed, requires an understanding of what once existed and how the conditions evolved from that initial state. It is also necessary to know what combinations of natural and anthropogenic factors forced the conditions to evolve. Further, it is necessary to appraise that rate at which evolution or change is likely to continue into the future and thus affect the success of any restoration efforts. To develop such an understanding of environmental change, and its effects on the present and future landscapes, requires an understanding of historical conditions. Environmental change can only be observed by comparing historical conditions to more recent conditions. In Sonoma it would be better to choose at least several historic milestones so that it can be determined if the rate of change is accelerating. How do we then build an understanding of historical conditions?

Several of the more historically oriented field sciences can elucidate information about earlier landscapes. Hydrological studies, tree ring analysis, fire scar analysis, paleontology, and other approaches can generate useful information about historical landscapes, but these generally provide information which is relatively course at the spatial or temporal scale. Fortunately, however, there generally exists a significant body of historical documents that can provide highly specific information about the hydrological and ecological features, catastrophic events, and impacts of land-use practices for a given watershed.

For the Sonoma Creek watershed, SFEI's previous historical research efforts focusing regionally on the Baylands and adjacent hydrological features, and have developed an archive of over 100 historical documents depicting early conditions in the Sonoma Creek watershed. These include archeological reports, Spanish documents, early federal maps, city and county records, and many other sources. Based upon the preliminary analysis of potential sources of historical data for the Sonoma Creek watershed completed for this report (outlined in Appendix 1), there are more than 1000 historical documents available at a variety of local archives. A list of SFEI's existing historical documents for the Sonoma area are attached in Appendix 2.

These potential historical resources (Appendix 1) represent a wide array of historical documents types. Based upon SFEI's previous research, many of these different types of documents will be applicable to the research questions central to this project (Table 8). In fact, because these documents were generated for purposes different from those of modern-day scientists, the collection and integration of a wide array of documents is crucial to the development of a strong historical data set. Diverse documents are essential both to build a network of information, which forms a strong, trustworthy historical picture, and to assess and calibrate the accuracy of historical sources (Grossinger 2000).

To interpret and integrate the diverse array of historical resources into useful products requires a methodology of documenting the synthesis of sources and assessing the accuracy of that synthesis. A system of certainty levels and integration of historical documents into a map with feature-by-feature documentation can be a particularly useful approach (Grossinger 2000). To carry out such an effort a research team must be developed. Important skills for the research team include archival skills, both in the collection of historical data and in the development of an archive and database at the project headquarters. It is also essential for the project team to have fluency in a variety of fields, including archeology, anthropology, geology, hydrology, plant community ecology, and history. The research team will need to be able to make preliminary data interpretations and communicate with experts in these fields.

Since no one individual can have expertise in each of these fields, it is important to develop a Project that has the stature, funding, and civic profile to attract involvement of local experts. To develop community involvement, and ensure the greater success of the project in developing information useful to local environmental planning, science, and education, SFEI recommends the development of a participatory Historical Ecology Project.

Table 8. The importance of historical analysis in ecosystem research, watershed management plan design, and implementation of restoration projects. This table is as an example of historical research design that is necessary prior to historical research.

Hypothesis	**Natural**	**Hydrograph**	**Channel Capacity**	**Water Backup**		**Physical**	**Ecological**
Examples of Potential Evidence	• hist. flooding accts.	• Δ in vegetation cover	• Δ in bed elevation	• Bayland modification	• Native Cultural sites	• natural tidal range	• native flora / fauna
	• settlement location	• Δ in channel connectivity	• Δ in channel banks	• sedimentation of tidal channels	• Spanish era sites	• natural salinity regime	• habitat use
Source		• dam construction	• flow restrictions	• Δ in tidal height	• early American sites	• channel / pan geomorphology	• hunting / fishing accts.
Ethnographic Documents	●	●	•	•	●	.	●
Archaeological Reports	●	•	•	•	●	•	●
Native Material Culture Analysis	●	●	•	.	●	•	●
Explorers' Journals	●	●	●	.	●	•	●
Spanish Disenos	●	•	.	.	●	•	•
Land-Grant Surveys	●	•	.	.	●	•	•
Land-grant Case Transcripts	●	●	●	.	●	•	●
U.S. Coast Survey Topographic Sheets	•	●		●	●	●	●
U.S. Coast Survey Hydrographic Sheets				●		●	●
General Land Office Surveys	.	●	.	.	.	.	•
City and County Maps	.	●	.	•	•	.	
U.S. Geological Survey Maps	.	●	.	•	.	.	
Accounts of Early Residents / Settlers	●	●	●	.	●	•	●
Early newspapers / magazines	●	●	•	.	●	.	●
Landscape Paintings	•	•	●	.	.	•	●
Landscape Photography	•	●	●	.	.	•	•
Aerial Photography, oblique / direct	.	●	.	●		●	
Botanical / Zoological Collections	•	●		●		•	●
Soils and Geology Maps / Reports	●	●	.	.			
Engineering / Planning Reports		.	●	•	.		
Local Histories	•	●	●	•	●	.	●
Oral Histories	●	.	•	.	●	.	●
Interviews with Longtime Residents	●	.	●	•	●	.	●

Integrated watershed approach

Most of the factors listed previously as possible contributors to flooding are having an influence on the magnitude of flood-associated damage in the Schellville area and Baylands. These factors included issues related to the entire spatial extent of the watershed. What remains unknown is the relative influence of each factor. If an analysis was performed that determined the contribution of each of the factors, a prediction could also be made on the best solutions to address the flooding problems. It is recommended that the solution to decreasing the risk to life, property, and life style associated with flooding will need to incorporate a number of measures to reduce the flood magnitude. Each measure will only have a small effect if applied alone but in concert, many small projects would potentially bring about effective reduction of flooding or at very least ensure that the problem does not worsen with inevitable future land-use changes and population increases. Indeed, the best way to reduce flooding is to adopt a whole-watershed approach that involves all members of the watershed community. The following are examples of the types of measures that "flood restoration" could involve:

1. *Set back levees in the lower watershed to increase flood conveyance*
2. *Increase levee heights and carry out levee maintenance on damaged levee systems*
3. *Provide high level bypass areas by carrying out environmental restoration in some parts of the Baylands*
4. *Place restrictions on housing development that ensure new developments generate minimum contributions to urban storm flow runoff*
5. *Encourage onsite retention or retardation of flood waters in urban and agricultural areas*
6. *Improve riparian structure and connectivity in an effort to slow the velocity of flood waters, reduce erosion, increase the roughness of channels, and enhance the recharge of ground waters*
7. *Limit channelization and channel modifications that speed up delivery of water to downstream areas*
8. *Encourage water retention measures on vineyards such as riparian management and set back levees*

9. *Encourage the use of cover crops to reduce soil erosion and reduce the flow rate of hill-slopes*
10. *Increase the tree cover in the open space and parklands areas of the watershed to increase the interception, groundwater recharge, and evapotranspiration potential of these areas*
11. *Re-establish flows in tributary channels that have been structurally modified, abandoned or dewatered by the influence of people. This would slow the ascending limb of flood hydrographs and increase habitat for species that rely on riparian and aquatic areas.*
12. *Community consultation and education on flooding issues, locations and causes*

This list is not exhaustive but serves as an example of how to break the problems associated with flooding into small doable project solutions across the whole watershed.

Integrated Bayland approach

The Sonoma Baylands are part of a larger system of physically, chemically and biologically related wetlands, sloughs, habitats, and farming communities called the Napa-Sonoma-Marsh. The connection between the Sonoma Marsh on the west and the more eastern Napa Marsh is very closely linked in both space and time. For example, a proportion of the volume of water and sediment derived or flowing through the First, Second and Third Napa sloughs in the Sonoma Marsh on the incoming flood tide could, on the outgoing tide and less than seven hours later, discharge or deposit in sloughs in the more eastern Napa Marsh system. Tidal and residual circulatory flows in the Napa-Sonoma-Marsh are a function of the system as a whole and not just any one part. Therefore, any change in the channel geometry, tidal excursion, timing and magnitude of floodwaters, geometry of the levee system, or environmental restoration of Baylands will certainly effect tidal flow, sedimentation, and habitats in other areas of the Napa-Sonoma-Marsh. To what extent this is important still remains unknown (i.e. what the effects will be and the magnitude of the effects). However, it is recommended that the best solutions for relieving damage associated with flooding and options Baylands restoration should take into account the Napa-Sonoma-Marsh system as a whole unit NOT a series of individual units. Some questions that could be asked include:

Q1. What are the design scenarios for flood mitigation and restoration in the lower Sonoma Creek watershed?

Q2. How will these design scenarios affect other natural habitat areas of the Napa Sonoma Marsh system?

Q3. What types of environments can flood mitigation create?

Q4. What are the spatial scenarios for the different habitats under different design scenarios for the Sonoma system?

Q5. What are the expected volumes of sediment required to carry out flood control and environmental restoration in the Sonoma system? Where in the Marsh systems will this sediment come from if it is not brought in reuse dredge spoils?

Q6. Are there any waste products associated with the design and if so how or where can these be disposed?

Q8. What effect will restoration scenarios have on the current design and success of existing projects in other parts of the Napa Sonoma Baylands?

Q9. What effects will restorations or flood mitigation designs have on the heights of floodwaters and the effectiveness of existing levees?

Benefit to Habitats and Species of the Watershed

Taken altogether, the actions undertaken for flood management purposes must also have a net benefit for the species and habitats that have been harmed or reduced by human activities over the last 180 years. This principle reflects not only the requirements of permitting agencies but also the wishes of many watershed residents. For instance, if riparian vegetation is replanted and managed in areas of the watershed where it has previously been lost, over the longer term there will be improvements in habitat connectivity, follow-on improvements in native species numbers and diversity, reductions in-stream temperature, increases in the complexity of in-stream habitat, improvements in groundwater recharge, reductions in bank erosion, improvements in water quality, and increases in carbon supply to the streams (the list could go on). Furthermore, and importantly for flood damage reduction in the lower watershed, there would be an increase in the time between peak rainfall in the watershed and the peak of the flood in the Schellville and

Baylands area. There would be a reduction in the peak flood height and a broadening of the flood wave due to increases in the roughness of the channel in upstream areas, increases in groundwater recharge, and retention in riparian areas.

Clearly, there is a strong association between reductions in flooding in the lower watershed and the integrity of habitat and biological communities in the entire watershed.

Preserving locations of importance

Any solutions for reducing the damage or risks associated with flooding and any solutions for restoring Baylands in the Sonoma Creek watershed will need to consider social aspects associated with:

1. Historical locations of importance such as old buildings and structures
2. Recreational uses such as walking trails, fishing spots, and hunting areas
3. Archeological locations of importance
4. Spiritual and esthetic locations such as middens and waterfalls
5. Environmental locations of rare habitats, sensitive species, or particularly species-rich habitats such as wetland or riparian area.

In many cases, locations of importance may be known collectively but may not be well enough documented in formal County plans or Environmental Assessment reports and may be overlooked in flood mitigation and Baylands restoration designs. It is suggested that part of the community consultation process should better define and prioritize locations of preservation importance.

Section 10.

Limitations of Existing Data

Hydrology

The design of any future projects that help reduce flood damage in the Schellville area will require accurate predictions of the timing, distribution, and magnitude of rainfall and runoff from the Sonoma Creek watershed. It is suggested that a minimum of ten years of data collection would be ideal. However, several years of data may provide some preliminary analysis suitable for modeling if it is augmented by data from the relatively data rich Napa River watershed. Several years of data would also allow refinement of the most cost effective network and methods for ongoing data-collection, analysis and modeling provided the years cover a range of watershed responses to rainfall (i.e., events of a variety of spatial rainfall distributions and magnitudes).

Using tipping bucket-type rain gauges, an accurate record of rainfall intensity can be calculated, and the exact distribution of rainfall through a storm can be recorded. Some are already in place throughout the valley with the ADCON system of rainfall data collection. The distribution of these should be reviewed to determine if they are adequate for modeling the hydrology of the lower Sonoma Watershed. Without a suitable network of tipping bucket-type rain gauges in the upper and lower watershed, it is not possible to determine the response time of storms in recent years. SEC is planning to reinstate the runoff gauge at Agua Caliente and this, coupled with their volunteer network of rainfall recorders, may measurements for rainfall intensity. If so, this will give an indication of the effects of land-use and population on the watershed response times.

Currently there is a lack of scientific data in regard to discharge and timing of flows from different parts of the Sonoma Creek watershed. At a glance, the watershed physiography indicates that the Schellville area is the collection point for water coming down from the upper Sonoma Creek watershed as well as water from the western ridges (Fowler Creek and its tributaries Champlin, Rodgers, Felder, Lewis, and Carriger) and from the eastern ridges (Nathanson and its tributaries, Arroyo Seco and Haraszthy). Although the eastern creeks don’t actually meet Sonoma Creek but instead flow out through Schell Slough, they still all meet on the floodplain that, during a larger event, is largely flooded. Flow gauging stations are needed in order to understand the contribution and timing of each creek to flooding in the Schellville and

Baylands areas. Ideally, a number of runoff stations in the lower watershed (Nathanson Creek, Fowler Creek, and Ague Caliente) should be set up for a minimum of two years (or longer if rainfall happens to be below average with no significant flood events).

Analysis of several years of data would probably provide a preliminary analysis of the proportional sources and timing of floodwaters for a range of storms. This information could be compared to gauging data from pre-1982 to determine changes of in runoff character over time. If runoff information was coupled with land-use, rainfall intensity (a tipping bucket rain gauge network should also be implemented at the same time) and information on stream physiography, a model could be developed to predict future responses to land-use changes and predictions of watershed response to different rainstorms. Without this sort of information it is difficult to do anything but hypothesize the future effects of changes in land-use on flooding. It would seem better in this report to pose a number of questions that may be used as staring points to drive any future efforts in watershed hydrological understanding. Examples of such questions are listed:

Q1. What is the discharge of water from each sub-watershed?

Q2. What is the response time of the watershed to incident rainfall and for the watershed at Schellville?

Q3. What is the discharge of sediments nutrients and pathogens from the watershed?

Q4. How do the response time compare to historical work carried out in the middle parts of the 20th century?

Q5. What effects will land use changes and population increases have on flooding in the Schellville area in the years 2005, 2015, 2025, 2050?

Q6. What effects will land use changes and population increases have on summer flows?

Q7. What is the recurrence interval for and stage height at Agua Caliente for discharge onto the floodplain near Schellville?

Q8. What is the return frequency of floods of a given stage height at Agua Caliente including maximum probable flood?

Q9. Has the return frequency changed over time?

Q10. What are the projected changes in flood frequency as a result of projected land use and population change (years 2005, 2015, 2025, 2050)?

Q11. What opportunities are there for reducing flooding in the lower watershed by implementing best management practices in riparian areas and re-establishing flows in abandoned tributary channels in the mid-watershed?

Q12. Does modeling suggest a statistical likelihood that BMP's can increase summer low flow or reduce flooding?

Q13. What is the direction and velocity of flow in flooded areas near and downstream of Schellville?

Q14. What is the area of flooded lands in the upper, middle and lower watershed for a range of given flood scenarios (now and in 2005, 2015, 2025, 2050, 2100)?

Q15. How will changes in riparian management in the upper watershed change the areas flooded in the upper watershed

A well-designed program to examine surface water hydrology should establish current conditions for monitoring trends, compare current situation with historical data, help analyze sediment data, calibrate sediment production models, test the relationship between discharge and in-stream habitat conditions (spawning gravel, etc), and test the relationship of discharge to land use. Low-flow studies should assess problem areas for fish rearing (pool numbers and depths), and explore links to water quality and temperature. Studies should assess expected discharge from precipitation input and compare it with measured discharge. An analysis of water rights and allocations, currently and in the future, would allow an assessment of how and where fish habitat might be affected by groundwater and in-stream withdrawals, and would track how much water might (or might not) be available for new allocations.

Geomorphology and Water Quality

As stated previously, any of the hypotheses for the contributing causes to flood damage in the lower Sonoma Creek watershed are linked to changes in channel morphology and changes in water quality (in particular, transport of sediment). It is therefore surprising that little quantitative scientific documentation has been done of either water quality or geomorphology. Given the changes in land use over the past two decades since the only quantitative study of suspended sediment transport (Anderson 1981), it seems likely that sediment load information may be outdated as well. Many questions remain unanswered:

Q1. What is the geomorphic character of the streams in the Schellville area?

Q2. What are the longitudinal profiles of the streams? Have they aggraded or degraded over time?

Q3. Do core analyses suggest a change in sediment supply, sediment source, and stream power?

Q4. Have the channel cross sections changed over time?

Q5. What effect does the Hwy 121 Bridge have on the morphology of the creek?

Q6. Are the changes in channel morphology the dominant cause of flood damage?

Q7. Has the volume and particle size of sediment changed over time?

Q8. Where is sediment that is eroded from middle and upper watershed streams deposited?

Q9. What is the relative proportion of sediment supplied from channels and from hillsides and vineyards, and what is the grainsize of this sediment?

Q10. What is the ultimate source of sediments that have filled the channels in the tidal Sloughs and has that changed over time?

Q11. Is the floodplain aggrading in the "bypass areas", and if so what is the rate of this aggradation?

Q12. Given the geomorphic character of stream reaches in the Schellville area and projected land use changes, what predictions can be made about the geomorphic character in 20 and 50 years' time and what will the likely effects be of changes in geomorphic character on flood damages in the future?

Q13. What is the condition of banks and the riparian vegetation in the middle and lower watershed?

These are just a few examples of questions that could be answered using a geomorphic approach such as the Watershed Science Approach (SFEI). There are many ways of determining these and other sediment / geomorphic questions. It is recommended that a study be done to determine sediment loads (suspended sediments and bed loads) in the three main tributaries to flooding in the lower Sonoma Creek watershed (Fowler, Sonoma Creek, and Nathanson). These should be carried out in conjunction with water discharge measurements. It is also recommended that a geomorphic study be carried out in creek reaches in the Schellville area. This will establish the changes in morphology and the rate that those changes are occurring. It will also establish detailed cross-sectional information, channel roughness, condition of banks and existing revetments, and accurate changes in channel slope. The geomorphic study should include sediment core analysis in recent sediment deposits in the channels between Schellville and San Pablo Bay. A variety of techniques such as organic/inorganic carbon ratios, magnetic susceptibility, sediment grainsize, and ^{137}Cs tracers could be used to determine the relative contributions of sediment from the watershed and Bay, how this has changed over time, and where sediment is derived from in the watershed. Water quality parameters such as temperature, bacterial loads, nutrients (primarily N and P), pesticides, dissolved oxygen (DO), conductivity, and pH should be monitored to identify point and non-point sources of pollution, identify restoration needs for human health and steelhead and aquatic species health, test relationships between water quality, land use, and riparian conditions, and allow testing of the effectiveness of restoration actions. Water quality collection efforts should be designed to provide information for the Clean Water Act 303(d) list of impairment.

Biology

Riparian conditions

Riparian extent and condition are important areas to research in support of Corps-related actions in the watershed. Changes in the extent, location, and composition of the riparian vegetative canopy affect bank stability and sediment input to the channel, recruitment of large woody debris to the channel for habitat complexity and cover, and stream temperatures. Riparian dysfunction has been identified by the Department of Fish and Game as a limiting factor for salmonids, and its impact can be felt by many species. The distribution of riparian vegetation is dynamic, changing locally and watershed-wide from natural processes and human impacts. Understanding trends in riparian vegetation is critical to restoration of riparian processes.

Negative direct or indirect impacts to the remaining riparian areas should be avoided, and projects should promote the natural recovery of riparian forests, lower-watershed riparian marshes, and these habitats' many dependent species. These priorities require up-to-date mapping of the location, extent, and ecological condition of remaining riparian areas, analysis of historic riparian communities and their locations, and making site-specific recommendations for an optimal restoration program.

Invasive species that have the capacity to degrade existing floodplain function and to conflict with desired restoration outcomes should be mapped and possibly eradicated. *Arundo donax* is certainly one of these; there may be others.

Sensitive species and habitats

Many species and several habitats in the riparian and Baylands ecological communities of the watershed are rare and/or endemic, as noted in previous sections. Some of these species and a range of others are considered sensitive by state and federal agencies. Because so much of the watershed is privately owned, there have never been consistent or complete surveys for occurrences of these species. Most surveys are done in preparation for environmental documentation related to entitlement permits and development projects. The California Natural Diversity Database attempts to track occurrences of these species on a statewide basis, but the program is under-funded and has no resources to collect field data.

What is needed is research on occurrences of rare, threatened, and endangered species in the riparian zone and Baylands. The habitat needs of these species can be ascertained by examination of the areas where they still survive. Once their needs are known, restoration actions can create these conditions with a degree of confidence that the species will increase. Unpublished reports, EIR's, and other documents will be scoured for information about the plants' locations. A workshop or series of meetings with community and agency experts could be conducted to collect this data. After this initial scan for existing information, a needs assessment will be conducted to determine opportunities for biological surveys.

Steelhead and California freshwater shrimp

Steelhead and freshwater shrimp are extremely high-profile species whose status can be improved by the project if the design process is supported by sound information on their locations, requirements, tolerances, and limiting factors. Some of this information will relate to general conditions, and other results may point to straightforward, site-specific restorative actions. SEC has begun a 3-year population study on steelhead that will provide much of this information for steelhead. Additional shrimp surveys should be conducted.

Benthic macro-invertebrates

Because of their diversity, ubiquity, and importance in the stream community as a major link in the food web, benthic macro-invertebrates (BMIs) provide an important indicator of aquatic health. BMIs are a major food source for salmonids and may be a limiting factor for survival of juvenile fish. EPA's Rapid Bioassessment Procedure groups samples into three pollution-tolerance categories and calculates a water-quality index. Programs of BMI sampling, such as those underway by SEC and others, would establish baseline community index values for sites that may be affected by restoration actions, so that restoration effectiveness can be tested.

Section 11.

Recommended projects and estimated costs

Introduction

It is recommended that an integrated approach relying on the principles described above be applied during a four to five year period to determine community and technical needs in relation to flooding and environmental restoration in the Sonoma Creek Watershed and Baylands (Figure 22). The advantage of the integrated approach is that it enhances the collaboration of the three main communities: science, management, and the public. Science, management, and public consultation will be brought together for a common vision of the watershed's future. Public consultation through all stages will ensure ownership of the final plan by all three communities. This collaboration will build a comprehensive, defensible watershed management plan, including recommendations for restoration.

The product of this process will be a document summarizing the results of studies and information gathered during the four to five year period, and making recommendations for design and implementation of projects devised during the integrated public, scientific and management consultation process.

The following projects are recommended based on the literature and materials discussed in this report, and discussions with landowners, community representatives, and at the Technical Advisory Workshop (Atwood Ranch, August 30, 2000). The projects are linked conceptually, physically in space and time, and should also be linked among organizations. Many of the projects will require information directly from other projects. Therefore, entities doing individual projects will need to strategize on how best to achieve their own goals, overall goals, while at the same time feeding information to each other. This will require plenty of communication and it will be necessary to ensure that strong relationships are forged and maintained.

Simultaneous Science and Management

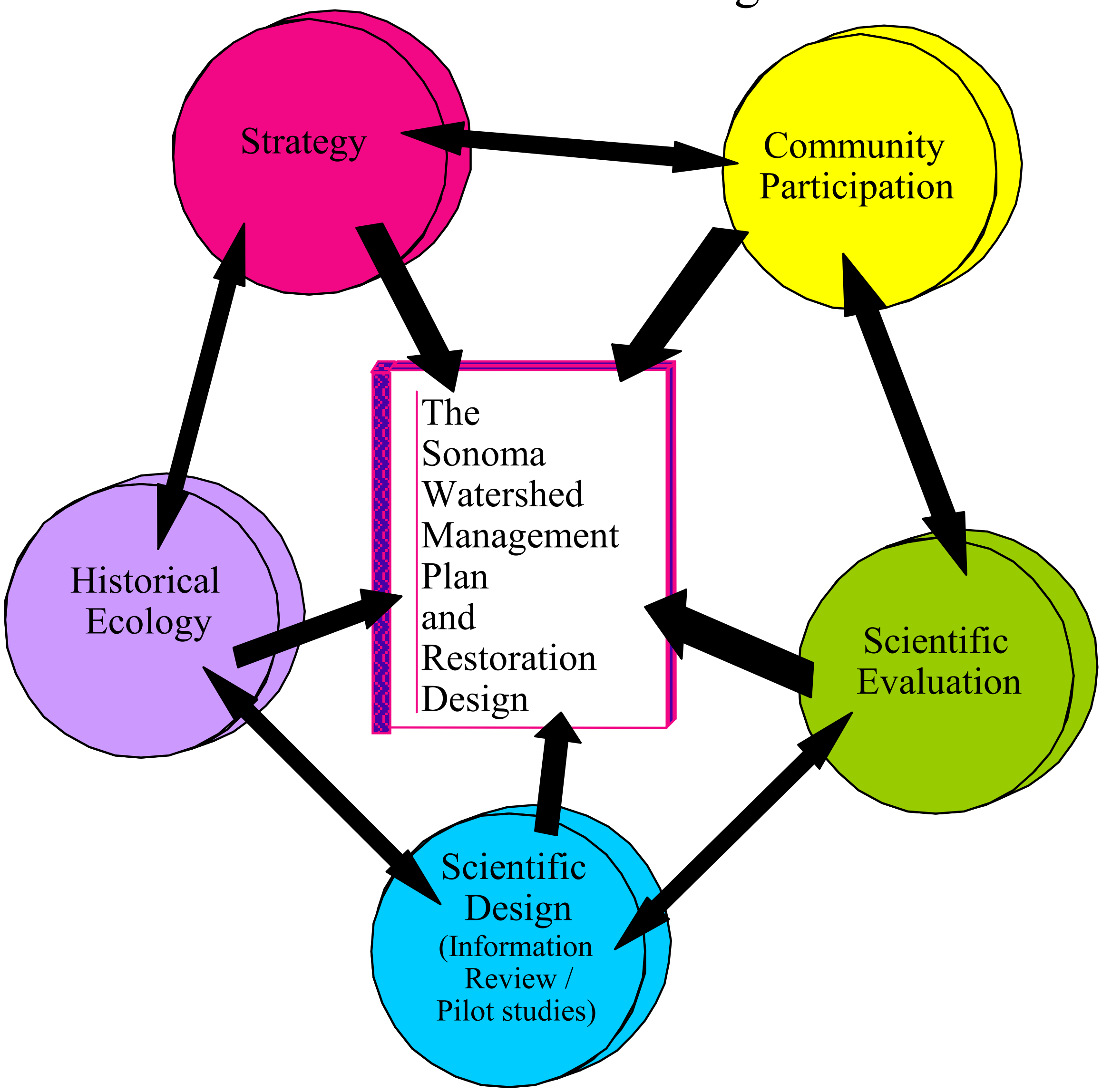


Figure 22. A conceptual diagram for information gathering and determining option for the future. This shows the way that the various facets of information generation link together to for a common consensus in the form of a management plan and design document. Such a process is likely to take four to five years.

Projects and Costs

1. Community consultation. Anecdotal understanding of the system: where it floods, what damage do floods do? What are the public needs, attitudes, concerns? Who should pay? Sharing technical understanding of watershed functioning with community. $300k.

2. Historical ecology. What were the historical types and distributions of flora and fauna in the watershed and Baylands? When were there floods and how big were they? Has flooding gotten worse over time? Was the flooding as bad before the drainage of the Baylands and the building of bridges? How did hydrologic and other ecological processes create various habitats and interact with flora and fauna? Has the water quality changed over time in the watershed and Baylands? Has the groundwater supply changed over time? $300k.

3. GIS mapping and surveys. Refinements and additions to SEC's GIS database will provide high quality spatial information for watershed and Baylands modeling. GIS data should include coverage's of both historic and contemporary land uses, vegetation types, soil/geologic formations, topographic data, rainfall "surfaces," wildlife habitats, sensitive species distributions and habitat requirements, water diversions/extractions, water quality data, and population distributions [of humans?]. In the case of rapidly changing land use types (such as areas of vineyards) this information should be mapped with higher temporal frequency and include the previous years distributions where possible. The GIS database should be designed to provide a tool for evaluating various scenarios of future conditions and monitoring changing conditions with adaptive management. $300k.

4. Hydrological and sediment loads evaluation of the Sonoma Creek watershed. Construct in-stream flow gauge and perform maintenance to measure watershed response to rainfall and stream response during storms. Perform rainfall data collection, both short- and long-term with small and large collection return intervals in sub-watersheds to evaluate rainfall response among watersheds and with respect to various land uses. Evaluate floodplain condition and routing patterns. Install continuous turbidity gauges, monitor

total suspended solids (TSS), and reduce and manage data to evaluate how much sediment is moving in main-stem Sonoma Creek and major tributaries during storms. Model flows, evaluate restoration alternatives, including sediment yield characteristics of sub-watersheds, to gain understanding of sediment production over time and given future land-use changes. Extend Annadel sediment yield analysis to entire watershed to understand soil type and soil moisture retention characteristics throughout the basin affect flooding in the lower watershed. Compile existing soil boring and groundwater monitoring information, construct soil moisture retention curves, to evaluate soil type and soil moisture retention characteristics throughout the basin. Which upper watershed projects will help to reduce total and peak flows in the Schellville? $350k.

5. Geomorphic analysis of the Schellville area (including lower Nathanson Creek, Sonoma Creek and lower Fowler Creeks). What effect does the geomorphic character in the Schellville areas have on flooding. Has it changed over time and what will it be like in the future given land-use changes? Which upper watershed land management schemes will help to reduce seasonal and total sediment delivery to the Schellville streambed? Evaluate sediment movement to gain understanding of which scenarios cause the greatest change in cross sections of Sonoma Creek (and cross sections of lower Nathanson and lower Fowler, potentially affecting flooding. $300K.

6. Sediment source analysis. Where is the sediment in the Sonoma Marsh coming from? What is the source gradient and how will that affect restoration projects? Has the source of sediment changed over time since the 1850's? For sediment derived in the upper watershed, what hill-slopes are most susceptible to erosion? Which sub-watersheds have the highest sediment yield and restoration potential? During floods what proportion of the sediment derived from the watershed is deposited in the Baylands and where is it deposited (channels, floodplain, wetlands etc)? What is the rate of accretion of sediments in different parts of the system and how will that affect wetlands recovery and flood magnitude in the future? $400k

7. Baylands modeling. Under different design scenarios for flood reduction, what will the new flood heights be in relation to levees current maintained by farmers in the Baylands. What effects will each scenario have on flood relief in Schellville and other areas of the Baylands What are (more effective) alternatives to levees? $250k

Section 12.

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Section 13
Appendices

Appendix 1.

Preliminary Analysis of Potential Historical Resources for Sonoma County Watershed Historical Ecology

There are two key library systems for California History that should be consulted. The first is the University of California at Berkeley and the second is the California State at Sacramento. Search should begin with Sonoma County but will have to include Early California History since many references are not county specific. In the Berkeley System there are several key libraries to search: The Bancroft library for early accounts, maps and photographs, the Anthropology library for reports of the Native Americans and early colonists, the map room and earth sciences for maps, aerial photographs, soil and geologic reports, the water resources library, for stream hydrography and geomorphology, water records, rainfall and sediment supply, and the Jepson Herbarium and Life Science library for flora and Fauna as well as fire studies. All masters thesis listed in these libraries specific to the Sonoma Creek watershed will be important to collect. A quick search of Sonoma County documents revealed 794 sources out of which 548 were worthy of further consideration.

The Bancroft library will contain important early explorer accounts, photographs and maps. There are seven important land grants in the watershed area with accompanying maps and 14 testimonies of 30 to 800 pages each. Three other land grants border the edge of the watershed and may provide relevant material.

The map room has Aerials as early as 1953 up to present time but the earliest aerials, usually in the 30's will have to be found and purchased from Pacific Aerial or another local source. The map room has 95 maps that pertain to Sonoma County, half of which will be repetitive but often the repetition is deceptive and may differ in fact in very key areas. There are 15 drawers of about 25-50 maps of general California data that can be useful especially when there is an atlas of each county. Of these roughly 35 maps will be important to the project.

The Bureau of Land Management in Sacramento has the original township and range surveys and survey notes that are very useful in locating landscape features especially in regards to vegetation. These include T6N.R6W, T6N.R7W, T5N.R7W, T5N.R6W, T6N.R5W, T5N.R5W, T4N.R5W, and T4N.R6W.

USGS library in Menlo Park holds key maps that may not be found elsewhere. They also have data on stream monitoring, soils, earthquakes and faults on their web site that is important for research.

Fish and Game will have some early records but most of those reports are found in libraries. After the 30's their records will be very detailed accounts of the stream. An estimated (1000 to 3000) records will have to be looked at for information.

Environmental impact reports and management studies of the Creek can provide information of historical change particularly after 1950. It is very helpful to check all EIR's registered with the county and to call the best consultants in the area for their EIR / EIS report. These reports can contain logs of boring holes and other references. There is often an historical section that can provide more bibliography for research. Roughly, 5% of the EIR's are useful.

Bibliographies of California History are helpful such as California Local History, A Bibliography and Union List of Library Holdings by Margaret Miller Roco, Stanford University Press, 1970. She lists 9 County Histories, 121 general references, 26 Sonoma references. Of these SFEI holdings represent 5%. An estimated 10% of total references will yield something useful. Most of these sources will describe people and buildings more than ecological history. However, the best account of people and buildings is very useful for understanding where people were and when and helps us understand the historical landscape. Miller Roco also lists 79 references for Santa Rosa and Petaluma that will have to be looked through to see if they contain references to Sonoma as well. Roughly 5% of these will prove useful.

When a solid source is found, all references in that key source will have to be collected because it is most useful to have original sources. Key sources will then emerge as multiple citations will occur and all key sources must be obtained. A key source that has already emerged in the research is Altimira's account that is cited in nearly every history and is understandable since he was on of the first European explorers to travel through the area and write about it. Jose Altimira's account; Diario de la expedicion verificado con objecto de reconocer terrenos para la nueva planta de las Mision de Maestro Padre San Francisco principiada le dia 25 de Junio de 1823. A Spanish dictionary is critical to the research. There is an English translation of this text.

Other general sources that are very useful are sources that study Place Names such as: Gudde, Erwin, California Place Names, Sanchez, Nellie, Spanish and Indian Place Names of California, DuGard, Rene, Dictionary of Spanish Place Names of the Northwest Coast of America, 1983, Hoover, Mildred, Historic Spots in California, 1937. Sources for these texts must also be evaluated for use for Historical Ecology. For instance, Hoover lists 15 sources for Sonoma County for 29 place name entries ranging from individual Spanish Land Grant names to Jack London and the Asti Colony.

Roughly 15% of the sources listed cover parts of Sonoma County outside of the Sonoma Creek watershed study area, namely Fort Ross and Mendocino County, Bodega Bay, Petaluma, Santa Rosa.

Native American and Anthropology Sources: Texts for use in Napa and Marin will also be important since for instance the Pomo, Wappo, and Miwok, Native American people traveled and lived in both counties. The Miwok Museum will be helpful. Heizer, Robert and Elsasser, Albert's A Bibliography of California Indians, Archaeology, Ethnography, Indian History, 1977 lists 246 records pertaining to California, North Coast ranges and San Francisco Bay that could be useful. Many Archaeological reports will reference other sites as reference points so the list will have to be analyzed for it's application to the Sonoma Creek watershed study area. Of these an estimated 50% will prove to be useful. The authors also list places to see the original material, Native American collections and photographs. For an in depth analysis of Native Land Practices, these collections are critical. There are many collections abroad in Germany and Russia for instance. Vane, Sylvia and Bean, Lowell in California Indians: Primary Resources, A guide to Manuscripts, Artifacts, Documents, Serial Music and Illustrations, lists 4 rancherias for reference; Cloverdale, Dry Creek, Stewart's Point and Ya Ka Ama. The key source for Archaeological Site Records is at Northwest Information Center, Department of Anthropology, Sonoma State University. Permission must be obtained for a visit and issues of disclosure must be addressed. They list the following museums as important for historical material; Fort Ross State Historic Park, Petaluma Adobe Park State Historic Park, Jesse Peter Native American Art Museum in Santa Rosa, Sonoma Public Library, Sonoma State Historic Park. Most of these sites are outside of the study area but their collections will have a wide range of material. The authors say that the Sonoma State Historic Park has no research materials on California Indians however there is an exhibit on Indian Culture. The Sonoma Valley Historical Society Museum will be a key resource as well as its members.

We have found that the volunteers at these historic Museums and Historical Societies, since they are history buffs themselves, know a tremendous amount and will know people to talk to. Most often they are helpful with family histories but they will have families to talk to. From Interviews with the people who work at these places roughly five names will emerge of people to talk to. All of these people should be interviewed and asked whom else to talk to. They will each list one other person for an interview and so on. Each person will have at least one valuable historical document or insight for the project. An excellent thesis on the Sonoma Historical Watershed will provide initial structure for the research.

Other important resources: The Sonoma Valley Historical Society and its publications, called Sonoma Valley Notes. Early Papers for the Sonoma Area such as, The Petaluma Journal Argus, the Agricultural Weekly, The Sebastapol Times, The Sonoma County Journal, Agricultural News, and The Sonoma County Tribune, can provide important historical events. The Sonoma Branch of the County Library System is a key place to investigate early papers, publications out of print and family histories. Other key sources are the Vasquez House, the Bouverie Audubon Reserve and the Photo collection of Mr. and Mrs. Charles Groskopf and the historical collection of Robert Parmalee, author of Pioneer Sonoma.

The county Clerk office is very useful for obtaining records of property survey-there is a lot of information to look through. Coy, Owen in his Guide to the County Archives of California, 1919 lists 159 record types. Of these ten types are useful, those mostly to do with land ownership and title transfer, land grants and swamplands.

County Archives in departments such as the Water District, Flood Management, Fish and Wildlife, Fish and Game, Fire Department, and the County Clerk have important sources.

There will be key interviews to conduct to further the investigation. Early on in the project these individuals will be identified. Some key individuals have already emerged through preliminary research. They are: Diane Smith, Archivist for Sonoma Valley Historical Society Museum, Mary Rede, Librarian for Sonoma branch of County library System, Susheel Bibbs, Marion Britton, Susan Bundschu, Jabez W. Churchill, Sylvia Crawford, Bob Glotzbach, Liz Parsons, Dallyce Sand, Milo Shepard, Pat and Win Smith, and Margaret Wiltshire.

Appendix 2.

SFEI existing historical document list collected and reviewed by SFEI

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Sonoma Valley Notes	Smilie, Robert	1973	native land-use, stream, fish		Sonoma		
Interviews with Tom Smith & Maria Copa	Collier, Mary E.		fish, native land-use, waterfowl, hunting		Sonoma and Marin		
Interviews with Tom Smith & Maria Copa	Thalman, Sylvia		fish, native land-use, waterfowl, hunting		Sonoma and Marin		
A Charmstone Site in Sonoma County	Elsasser, Albert	1955	native land-use	Sonoma	Sonoma	Sonoma	Sonoma
Archaeological Survey of Minor Lot Split, 800 Acres at 6542 Lakeville Highway, Sonoma County, California	Flynn, Katherine	1986	native land-use, stream, land/property survey	Sonoma, Petaluma	Sonoma	Hog Island, Sonoma	Petaluma
Cultural Resources Evaluation of the Tolay Valley Proposed Wastewater Reservoir Area, Sonoma County, California	Chavez, David	1979	native land-use	Tolay	Sonoma	Tolay Valley	Tolay
California, San Francisco and Vicinity	Unknown	1902	land/property survey, stream, topography	Tolay, Napa, Sonoma, Montezuma, Suisun	Napa, Fairfield	Napa, Suisun City	Hastings, Seal, Huichica
Landcase map B 673, No. 333 ND	Leavenworth, T.M	1860	land/property survey	Sonoma	Sonoma	Sonoma	Agua Caliente
Landcase map B666, No. 327 ND	unknown	1850's	land/property survey	Sonoma	Sonoma	Sonoma	Aqua Caliente
Landcase map D 493 No. 227 ND	unknown	1850's	land/property survey	Sonoma?	Sonoma	Sonoma	Ayoska
1937 Official Sonoma City Map	unknown	1850's	land/property survey	Sonoma, Tolay	Sonoma	Sonoma	Carriger, Tolay
Map of Sonoma County California	Bowers, A.B.	1867	land/property survey, roads/trails, drainage alterations, topography	Sonoma	Sonoma	Sonoma	Agua Caliente, Calabasas, Carriger

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Map Number Ten			land/property survey, roads/trails, stream, topography	Sonoma, Petaluma	Sonoma, Petaluma	Sonoma, Rancho Petaluma	
Map of Sonoma County California, And portions of Napa County and Marin County Cal.	Ricksecker, L.E.	1902	land/property survey, drainage alterations, roads/trails, stream	Sonoma	Sonoma	Sonoma	San Antonio, West, Petaluma, Huichica
Landownership Maps- 0044CA Sonoma 1900		1900	land/property survey, topography, stream, roads/trails	Sonoma, Petaluma	Sonoma	Sonoma	Carriger
Memoirs of the Vallejo	Vallejo, Platon Mariano guadalupe	1994	bay, native land-use, bear	Sonoma	Sonoma	Sonoma, Napa	Sonoma
Map of a Part of Petaluma Creek, California	Unknown	1860	stream, topography	Petaluma	Sonoma	Petaluma	Petaluma
The Mahilkaune Pomo and their neighbors: an entho-historical study of the Warm Springs Dam and Lake Sonoma Project, Sonoma County	Bean, Lowell John	1974	stream, native land-use, vegetation, fish	Sonoma	Sonoma	Sonoma	Sonoma
The Mahilkaune Pomo and their neighbors: an entho-historical study of the Warm Springs Dam and Lake Sonoma Project, Sonoma County	Hirtle, Jr., Eugene	1974	stream, native land-use, vegetation, fish	Sonoma	Sonoma	Sonoma	Sonoma
An Illustrated History of Sonoma County, California			plants, stream	Sonoma	Sonoma	Sonoma	Sonoma, San Antonio
Archaeological Test Excavations at CA-SON-25H, -26, -1940, and -1941 in the Los Guilicos Locality, Sonoma County, California	Alvarez, Susan	1993	native land-use, tidal marsh, vineyard	Sonoma	Sonoma	Sonoma	Sonoma
Archaeological Test Excavations at CA-SON-25H, -26, -1940, and -1941 in the Los Guilicos Locality, Sonoma County, California	Dowdall, Katherine	1993	native land-use, tidal marsh, vineyard	Sonoma	Sonoma	Sonoma	Sonoma
Archaeological Test Excavations at CA-SON-25H, -26, -1940, and -1941 in the Los Guilicos Locality, Sonoma County, California	Fredrickson, David	1993	native land-use, tidal marsh, vineyard	Sonoma	Sonoma	Sonoma	Sonoma

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Comrades and Chicken Ranchers- the Story of a California Jewish Community	Kann, Kenneth			Petaluma	Sonoma	Petaluma	Petaluma
Report of the Commissioners of Fisheries of the State of California for the Years 1874 and 1875	Unknown	1875	fish, stream, species introduction, tidal salinity		Sonoma, Napa, Solano, Alameda, Sacramento	Suisun Region	Napa, Sacramento
The San Francisco Call, Saturday, March 28, 1896	Unknown	1896	fish, stream, fishing	Guadalupe, Coyote, Los Gatos, San Pablo, Wildcat,	Alameda, Sonoma, Marin, Santa Clara	San Francisco Bay Area	Corte Madera, Ross, Lagunitas, Novato, Olema, Arroyo San Antonio, Sonoma, Agua Caliente, Flwler
Pacific Sportsman, vol. 14, no 12	A., R.E.	1934	fish, stream, waterfowl, hunting	Napa, Sonoma	Marin, Sonoma, Napa	North Bay, Mill Valley	Napa, Sonoma
The San Francisco Call, Saturday, March 9, 1895	Unknown	1895	stream, fish, fishing, waterfowl, hunting	Sonoma	Sonoma	Embarcadero (Sonoma	Sonoma
The San Francisco Call, Saturday, March 16, 1895	Unknown	1895	stream, fish, hunting, waterfowl	Sonoma	Sonoma	Sonoma	Sonoma
The San Francisco Call, Saturday, March 23, 1895	Unknown	1895	stream, fish	San Leandro, Wildcat, Lagunitas, Sonoma	Sonoma, Alameda, Contra Costa, Marin	Marin, Sonoma, Alameda, Papermill, Berkeley	Alameda, Papermill, Lagunitas, Wildcat, San Leandro, Purissima
The San Francisco Call, Saturday, March 30, 1895	Unknown	1895	stream, fish, climate	San Mateo, Sonoma	Sonoma, Marin, San Mateo, Santa Clara	San Mateo, Sonoma, Santa Clara	Nicasio, Sonoma
The San Francisco Call, Saturday, April 27, 1895	Unknown	1895	stream, fish, fishing	Sonoma	Sonoma	Sonoma	Sonoma
The San Francisco Call, Saturday, April 20, 1895	Unknown	1895	stream, fish, fishing, species introduction	San Mateo, Sonoma, Marin	Sonoma, San Mateo, Marin	Sonoma, San Mateo, Marin	
The San Francisco Call, Saturday, June 22, 1895	Unknown	1895	fishing, fish	Sonoma?	Sonoma		Pieta, Sulphur

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
The San Francisco Call, Saturday, February 1, 1896	Unknown	1896	fish, fishing, waterfowl, hunting	Sonoma, San Gregorio	Sonoma		Sonoma, San Gregorio
The San Francisco Call, Saturday, April 13, 1895	Unknown	1895	fish, fishing, species introduction	Los Gatos	Santa Clara		Los Gatos, Boulder, Sonoma
The San Francisco Call, Saturday, April 4, 1896	Unknown	1896	fishing, fish, stream, rainfall	Guadalupe, Wildcat, Sonoma, [mount tam]	Marin, Sonoma, Contra Costa	Marin, Sonoma, Mout Tamalpais, Wright Station	Los Gatos, Wildcat, Sonoma
The San Francisco Call, Saturday, May 16, 1896	Unknown	1896	fishing, fish, stream	Sonoma, Salmon	Sonoma, Marin	Marin, Sonoma	Salmon, Sonoma
The San Francisco Call, Saturday, May 30, 1896	Unknown	1896	fishing, fish, stream, pollution, grazing	Sonoma	Sonoma	Glen Ellen	tributary off Sonoma Creek
The San Francisco Call, Saturday, November 16, 1895	Unknown	1895	fish, fishing	Sonoma, San Pablo	Contra Costa, Sonoma	Orinda, Sonoma	Sonoma, San Pablo
The San Francisco Call, Saturday, August 29, 1896	Unknown	1896	fish, fishing, stream	Sonoma	Sonoma	Sonoma, Glen Ellen	Glen Ellen, Sonoma, Kenwood
The San Francisco Call, Saturday, December 19, 1896	Unknown	1896	fish, stream, fishing	Sonoma	Sonoma	Shellville	Sonoma
The San Francisco Call, April 30, 1917	Unknown	1917	fish, stream, fishing	Stevens, Los Gatos, Campbells, Napa, Mill	Santa Clara, Napa, Sonoma	Napa, Santa Clara, Sonoma	Napa, Conn, Campbells, Stevens, Los Gatos, Mill, Little Sulphur, Mark West
The San Francisco Call, May 9, 1909	Unknown	1909	fish, fishing, hunting, birds	Coyote, Sonoma,	Sonoma, Santa Clara, Alameda	Brookdale, Gilroy Hot Springs	Coyote, Sonoma
The San Francisco Call, Saturday, May 9, 1903	Unknown	1903	fish, fishing, stream	Sonoma	Sonoma, Mendicino	Mendicino, Sonoma	
Petaluma Enquirer, March 22, 1977	Jettings	1877	fish, stream	Sonoma, Corte Madera	Marin, Sonoma	Marin, Sonoma	Marin, Sonoma
Petaluma Courier, May 2, 1878	Unknown	1878	fish, stream	Sonoma	Sonoma		Sonoma
Agua Caliente Thaddeus M. Leavenworth clmt. land case	Tracy, C.C.	1860	stream	Sonoma	Sonoma Marin		Petaluma, Agua Caliente
Ranchos in Northern Marin and Southern Sonoma Counties	Unknown	1870	stream	Sonoma	Sonoma Marin		

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Birdseye View of Petaluma, Sonoma 1871	Unknown	1871	stream	Petaluma	Sonoma Marin		
Historical Atlas Map of Sonoma County California	Thompson & Co., Thomas H.	1877	stream	Sonoma	Sonoma Marin		
Illustrated Atlas of Sonoma County California	Reynolds and Proctor	1898	stream	Sonoma	Sonoma Marin		
Map Showing railroad and Shipping Facilities of Sonoma County	Smith, Newton V.V.	1800	railroad	Sonoma	Sonoma Marin		
Sonoma County Early Rancho Map	Unknown	1800s	stream	Sonoma	Sonoma Marin		
Map of Sonoma	Peabody, E.T.	1854	stream	Sonoma	Sonoma		Sonoma
Alameda County School Districts		1874	stream	Wildcat, Novato, San Leandro, San Pablo, Sonoma	Alameda Sonoma Marin		
Rancho de Huichica Sonoma	Leese, Jacob	1861	stream	Sonoma		Huichica	Arroyo de los Carneros, Arroyo seco
Sonoma, CA	Unknown	1888	stream	Sonoma	Sonoma		
Map of Lachroma Montis and other property of Gen. M. G. Vallejo in the city of Sonoma							
The Sonoma Mission San Francisco Solano de Sonoma, the Founding, Ruin and Restoration of California's 21st Mission	Smilie, Robert	1975	water sources	Petalulma, Sonoma, Napa	Napa, Sonoma		
San Pedro, Santa Margaria, and Las Gallinas	Leese, Jacob		stream	Petaluma	Sonoma		
Soil Survey of Sonoma County, California	Miller, Vernon	1972	soils	Sonoma	Sonoma Marin		Sonoma
Soil Survey of Sonoma County, California	Miller, Vernon	1990	soils	Sonoma	Sonoma Marin		Sonoma

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Cultural Resources Evaluation of the Tolay valley Proposed Wastewater Resevoir Area, Sonoma County, CA	Chavez, David	1979	archaeology	Sonoma	Sonoma Marin	Tolay	Tolay
Sonoma County Atlas	Thompson, Thomas	1877	stream	Sonoma	Sonoma Marin		Sonoma
California Sonoma Quadrangle Grid Zone "G"	Unknown	1919	stream	Sonoma	Sonoma Marin		Sonoma
Saga of Sonoma in the Valley of the Moon	Unknown	1976	vegetation	Sonoma	Sonoma Marin		Sonoma
T-5935 San Pablo Bay Napa River-Sonoma Creek and Vicinity	US Coast Survey		stream	Sonoma	Sonoma Marin Napa		Sonoma
T-4018 Sonoma Creek, Hideman Slough	US Coast Survey	1922	Tidal marsh	Sonoma	Sonoma Marin Napa		Sonoma
T-4017	US Coast Survey	1921	Tidal marsh	Sonoma	Sonoma Marin Napa		Sonoma
T-564	US Coast Survey	1856	Tidal marsh	Sonoma	Sonoma Marin Napa		Sonoma
T-1826	US Coast Survey	1886	Tidal marsh	Sonoma	Sonoma Marin Napa		Sonoma
Sonoma and Marin Rail-Road Map	Stangroom, M.L.	1875	Railroad	Sonoma	Sonoma Marin		Sonoma
Sonoma Valley Notes, Volume 4.		1975		Sonoma	Sonoma Marin		Sonoma
City of Sonoma, from Sonoma Valley Notes, Volume 4.		1851		Sonoma	Sonoma Marin		Sonoma
Sonoma Valley Notes, Volume 3.		1973		Sonoma	Sonoma Marin		Sonoma
Sonoma Valley Notes, Volume 7.		1977		Sonoma	Sonoma Marin		Sonoma

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Map Showing the Route of the North Pacific Coast Rail Road Through Marin and Sonoma Counties	Newton V.V. Smith	1890	Railroad	Sonoma, Napa, Petaluma, Mill Valley	Marin, Sonoma, Napa	Sonoma, Napa, SantaRosa, Tomales, Fairfax	Napa, Sonoma
Sonoma Creek.	Armstrong, William Weaver	1890	stream	Sonoma	Sonoma		Sonoma
Sonoma	Corps of Engineers,US Army Tactical Map	1915	stream	Sonoma, Napa	Sonoma, Napa,	Sonoma, Napa,	Sonoma, Napa
Napa	US Geological Survey	1896	topography	Sonoma, Napa	Sonoma, Napa,	Sonoma, Napa,	Sonoma, Napa
Topographic Map of the Tomales Bay, Santa Rosa and Napa Areas Showing Indian Camp Sites	Department of Anthropology, University of California and Jesse Peter	1903	native land-use	Sonoma,Santa Rosa, Petaluma	Sonoma, Napa, Marin	Glen Ellen, Kenwood, Cotati	Sonoma, Carriger, Petaluma
Santa Rosa	US Geological Survey	1914	Land-use	Sonoma,Santa Rosa, Petaluma	Sonoma, Napa, Marin	Glen Ellen, Kenwood, Cotati	Sonoma, Carriger, Petaluma
Sonoma Baylands, State Coastal Conservancy and Sonoma land Trust	Gahagan and Bryant Associates, Inc.	3/24/09	stream	Sonoma	Sonoma	Sonoma	Sonoma
History of Petaluma	Heig, Adair	198?		Sonoma, Petaluma	Sonoma, Marin	Sonoma, Petaluma	Sonoma, Petaluma
B-672, Thaddeus M. Leavenworth, Claimant, "Agua Caliente"	Unknown	1850's	streams	Sonoma	Sonoma	Agua Caliente	Sonoma, Agua Caliente
Landcase map for C.P. Stone, Claimant "Aqua Caliente" part of Sonoma County	Unknown	1850's	steams	Sonoma	Sonoma	Agua Caliente	Sonoma, Agua Caliente
Sello Quinot Medio Real or Guenoc, Archibald Ritchie Claimant.	Unknown	1845	streams	Sonoma	Sonoma	Guenoc	
Sonoma CA	Sanborn Map and Publishing Co.	1888	streams	Sonoma	Sonoma	Sonoma	Sonoma
Map of the Land of Petaluma	County Surveyor	1848	streams	Sonoma, Petaluma	Sonoma, Marin	Sonoma, Lake tolay,	Sonoma, Petaluma

Table continues

Primary Source Title	Author	Year	Keywords	Major Watershed	County	Place Nape	Stream
Sketch of Lake Tolay and Lakeville	Unknown	1840's		Sonoma	Sonoma	Lake Tolay	Sonoma
Petaluma, M.G. Vallejo	Hardenburgh, I.R.	1872		Sonoma, Petaluma	Sonoma, Marin	Petalluma, Cotate, Sonoma	Petaluma, Sonoma
D-110, Jacob P. Leese, Claimant, "Huichica" Sonoma County	Unknown	1854	streams	Sonoma	Sonoma	Sonoma	Sonoma
Township No. 3 North. Range No. 5 West, Mount Diablo Meridian.	Brown, W. H.	1860	vegetation	Sonoma, Napa	Sonoma	Midshipman's slough	Sonoma
	Unknown	1850	streams	Sonoma			
d-111, Diagram of a Survey of Huichica	Farrell, J	1844	streams	Sonoma	Sonoma	Sonoma	Sonoma
A 197, Juan Wilson, Claimant "Guilicos" Sonoma County	Unknown	1850's	streams		Sonoma	Sonoma	Sonoma
D-108, Jasper O' Farrell, Clmt. "Canada de la Jonive" Sonoma County	Fisher, George	1855	streams		Sonoma		
B-419, William Forbes, Clmt. "La Luguna de los Gentiles" or "Ceslamayome" Sonoma County	unknown	1850's	laguna		Sonoma		
B-795, J. Jesus Pena, et al, Claimants "Tzabaco" Sonoma County	Unknown	1850's	streams		Sonoma		
Map of Glen Ellen Sonoma Co. California	Davis, P.R. and Alston, Geo. P.	1888	Land-use	Sonoma	Sonoma	Glen Ellen	Sonoma
From Arrowhead Mountain to Yulupa, The Stories behind Sonoma Valley Place Names	Dawson, Arthur	1998	Land-use, streams, fish	Sonoma	Sonoma	all	Sonoma
Sonoma Valley Notes	Sonoma Historical Society	1975	stream	Sonoma	Sonima	Huichica, Lakeville	Sonoma
Aerial view looking North Sonona Creek in Foreground	Hall, Robert	1910	vegetation	Sonoma	Sonoma	Sonoma	Sonoma
Aerial view west	Hall, Robert	1910	vegetation	Sonoma	Sonoma	Sonoma	Sonoma

Appendix 3.
GIS coverage's held by SEC

General Name	Extent	Key Attributes	Source	File type	Feature type	File name	Data type
Annadel Geology	Annadel SP area	Bedrock geology type	digitized from USGS maps	Shape	Polygon	rockunit.shp	1:24k
Annadel Hydrology	Annadel SP area	flow accumulation; flow direction; path length; upslope catchment area; subwatersheds	derived from 30m DEM	Grid	Raster	multiple	30m
Annadel Soil	Annadel SP area	Soil type; k-factor	SCS 1:20K series	Grid	Raster	soils5.shp	30m
Annadel subwatersheds	park boundary and adjacent areas	area; mean elevation; trail/road density; average slope; etc.	30m DEM	shapefile	polygon	watersheds_clip2.shp	1:24k
Annadel trails	Annadel SP boundary	name; condition; inches of downcut; width; status; planned restoration	GPS data from Mike Bobbitt	Shape	Line	trails.shp	>1:2K
Annadel Vegetation	Annadel SP boundary	vegetation community type	SSU student field work	Shape	Polygon	veg_type.shp	>1:12k
Arundo locations	watershed	size; height; notes; history	SEC field work	shapefile	point	arundo.shp	1:24k
Bay area open space	bay area counties	type: title/easement; organization; county; name; acreage; level	GreenInfo Network	coverage	polygon	ba_os	1:24k
City of Sonoma land use plan	city limits	Land use designation; density	scanned general plan map	Shapefile	Polygon	son_genp.shp	1:12k
City Riparian Setback Zones	City of Sonoma Boundary	Name, Buffer Distance, Regulator Agency, Area, Perimeter, Acres	City of Sonoma Zoning District	Shapefile	Polygon	citybuffer.shp	1:24k

Table continues

General Name	Extent	Key Attributes	Source	File type	Feature type	File name	Data type
City riparian vegetation	Sonoma City Boundary	Name, vegtype, area, perimeter, acres	clipped from vegpoly.shp	Shapefile	Polygon	City Vegetation	1:24k
City tree inventory	city of Sonoma	species	GPS data	shapefile	point	tree_geoc.shp	1:2k
County flood plains	Sonoma county	Zone; Community; floodway	FEMA	Coverage	Polygon	sonoma_flood	1:24k
County General Plan Land Use	Sonoma County	land use designations; building density	unknown	Coverage	Polygon	genplan	1:24k
County government lands	Sonoma & Napa county	name; type	Tim Pudoff, Sonoma County	Coverage	Polygon	napagov; sonogov	1:24k & 1:100K
County Riparian Setback Zones	city and adjacent areas	Name, Buffer Distance, Regulator Agency, Area, Perimeter, Acres	Sonoma County General Plan Open Space Element	shapefile	Polygon	countybuffer.shp	1:24k
Fisherman's survey	asbury, calabazas, bear, graham, stuart creeks	fish status; habitat type; channel type; pool depth; water quality; temperature; substrate data; etc	1996 Stream survey NEAP	Shapefile	Polygon	multiple	>1:2K
FMMP farmland data	Sonoma County	importance, type, soil	FMMP web site	shapefile	polygon	sonoma_fmmp.shp	1:100k
Habitat corridor focus lands	SDC area	owner name, area, land use type, APN	CAD drawings	shapefile	polygon	focus_lands.shp	1:24k
Habitat Corridor lakes	SDC area			Shapefile	Polygon	Hab_cor_lake.shp	1:24k
Habitat corridor parcels	SDC area	Owner name, land use type	County CAD drawings	Coverage	polygon	Hab_lu3	1:24k

Table continues

General Name	Extent	Key Attributes	Source	File type	Feature type	File name	Data type
Jack London Trails	Jack London State Park/Sonoma Mtn area	name, surface, length	GPS data collection	shapefile	line	Trail.shp	
Landsat Imagery	North Bay	multispectral satellite data	Larry Fox, HSU	Image	Raster	45_33.img	30m
Landsat riparian veg	Sonoma County/CA	vegetation types, size class, whr type	CDF	Grid	Raster	riparian	30m
Landsat vegetation	entire watershed/CA	vegetation types, WHR, size	CDF	Grid	Raster	hard_wood	30m
Major Roads	Sonoma Valley Watershed	road name; type; route number		Shapefile	Line	Major_rd.shp	1:24k
Manholes	Sanitation district	depth; lateral; name; description; size; source	SCWA CAD files	shapefile	point	manholes.shp	1:12k
Minor Roads	Sonoma Valley Watershed	name, type, route number		shapefile	line	Minor_rd.shp	1:24k
Parcels	sanitation district boundary	APN; land use, zoning, general plan LUD; metroscan attributes	SEC via SCWA contract	Shapefile	Polygon	sanitation_parcels.shp	>1:2K
Riparian Vegetation	city of sonoma and adjacent areas	name, vegtype, area, perimeter	digitized from 1999 DOQ	Shapefile	polygon	vegpoly.shp	1:24k
Road/creek intersections	city of sonoma and surrounding areas	Creek name @ crossing, length at crossing	digitized from 1999 DOQQ	Shapefile	Points	Roadcross.shp	1:24k
Sanitation district boundary	watershed	area, perimeter	SCWA CAD file	shapefile	polygon	sanitation_boundary.shp	1:12k
SEC 1999 stream hydrology	Sonoma City and surrounding areas	Name, type of change, width and length	1951 USGS quad>1999 DOQ	shapefile	Line	creeks	1:12k

Table continues

General Name	Extent	Key Attributes	Source	File type	Feature type	File name	Data type
SEC monitoring sites	watershed	monitoring type; dates; name; location	SEC watershed map	shapefile	point	svwsmonitor.shp	1:24k
Sewer lines	Sanitation District	lateral; size; description; length; type	SCWA CAD files	shapefile	line	lines.shp	1:12k
SLT easements & titles	Sonoma County	name; type of protection; description, acreage	Sonoma Land Trust	coverage	Polygon	slt_lands	1:24K
Topographic contours	watershed	elevation in feet	USGS 10m DEM	shapefile	line	contour40.shp	1:24k
USGS 10 meter DEM	watershed and adjacent areas	ground elevations, slope, aspect, hydrologic derivations	USGS BARD	Grid	raster	by quad	10m
USGS 250k Quad maps	Napa quad	scanned map	USGS chart tiff	Image	Raster	c38122a1.tif	1:250k
USGS 30 meter DEM	entire north bay	elevation model; topo lines; hydrologic modeling: catchment area, slope length, hillshade, etc.	USGS 30m DEMs	Grid	Raster	sfbaydelta_ft	30 m
USGS 7.5' quad maps (DRG)	sonoma creek watershed	scanned 7.5' quad maps	CA Land Commission	Image	Raster	multiple	200ft pixel
USGS DOQQs	watershed & adjacent areas	digitized, ortho-corrected aerial photography (1994)	USGS	Image	Raster	multiple by quarter quad	1m pixel
USGS hydrology	entire Napa 1:250k quad sheet, most of North Bay	linear and area water features: streams; waterways; lakes; channels	USGS DLG	Coverage	Line/Polygon	hydro5	1:24k
Watershed Conservancy projects	watershed	name; organization; type; project description	SEC watershed map	shapefile	point	projects_99.shp	1:24k

Table continues

General Name	Extent	Key Attributes	Source	File type	Feature type	File name	Data type
Watershed Geology	portions of valley; entire north bay done summer 2000	bedrock geology types	digitized from USGS maps	Coverage	Polygon	rockunit.shp	1:24k
Watershed Slope	Annadel SP area	steepness (degrees)	derived from DEMs	Grid	Raster	slope1	10m & 30m
Watershed Soils	flat portions of watershed; grape growing areas	soil type	1972 SCS survey maps digitized by Hopland	Coverage	Polygon	soils.shp	1:20k
Watershed surface hydrology	Sonoma Valley Watershed	Creek names, type, status	USGS DLG	Shapefile	Line	Son_vly_hydro.shp	1:24k