Central Coast Regional Water Quality Control Board

Salinas River Sediment TMDL

Preliminary Project Report

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1 Overview

Scene 1 – 1930's: It's night on the Salinas River and the river level has dropped after a big storm. Two brothers enter the river near Paso Robles and drive stakes at even intervals across the river into the sandy river bottom. Next they stretch chicken wire across the river on the upstream side of the stakes so the water will hold it against the stakes. A dimly lit kerosene lamp is hung on the center stake then the brothers retreat to the bank to watch and wait while keeping one eye out for the warden. The lantern jiggles as the fish tries to push through the wire mesh and they rush in to capture their prize, the first steelhead of the season (adapted from Franklin, 1999).

Scene 2 - 2001: It's night on the Salinas River and it's raining hard. Safety equipment is set in the road in order to warn drivers that there are workers up ahead. A crane is set on the bridge and the sampler is lowered into the river's swift current. The field crew from the Watershed Institute is out taking samples from the river in hopes of shedding some light on why steelhead have all but disappeared from the Salinas River Watershed.

Seventy odd years separate these two scenes. What has happened in the intervening years to cause the collapse of the steelhead fishery in the Salinas River Watershed? Have sediment loads in the river increased to a point that steelhead are pushed to their limit? Have changes in the lower river affected critical habitat? Have the Nacimiento and San Antonio Dams caused the steelhead's demise by blocking access to spawning and rearing habitat and by capturing winter storm flow from the Santa Lucia Mountains? Did DDT used for mosquito abatement and crop protection have an impact on the steelhead? Did the drought in 1947-51 play a role in the steelhead's decline? Or is it some combination of these and other factors?

Our work over the past couple of years has led us to the conclusion that while sediment may have a negative effect on beneficial uses within the main stem of the Salinas River the effects appear to be secondary with respect to other stressors affecting the system.

The Salinas River

From both sides of the valley little streams slipped out of the hill canyons and fell into the bed of the Salinas River. In the winter of wet years the streams ran full-freshet, and they swelled the river until sometimes it raged and boiled, bank full, and then it was a destroyer. The river tore the edges of the farm lands and washed whole acres down; it toppled barns and houses into itself, to go floating and bobbing away. It trapped cows and pigs and sheep and drowned them in its muddy brown water and carried them to the sea. Then when the late spring came, the river drew in from its edge and the sand banks appeared. And in the summer the river didn't run at all above ground. Some pools would be left in the deep swirl places under a high bank. The tules and grasses grew back, and willows straightened up with the flood debris in their branches. The Salinas was only a part-time river.

John Steinbeck, *East of Eden, 1952*

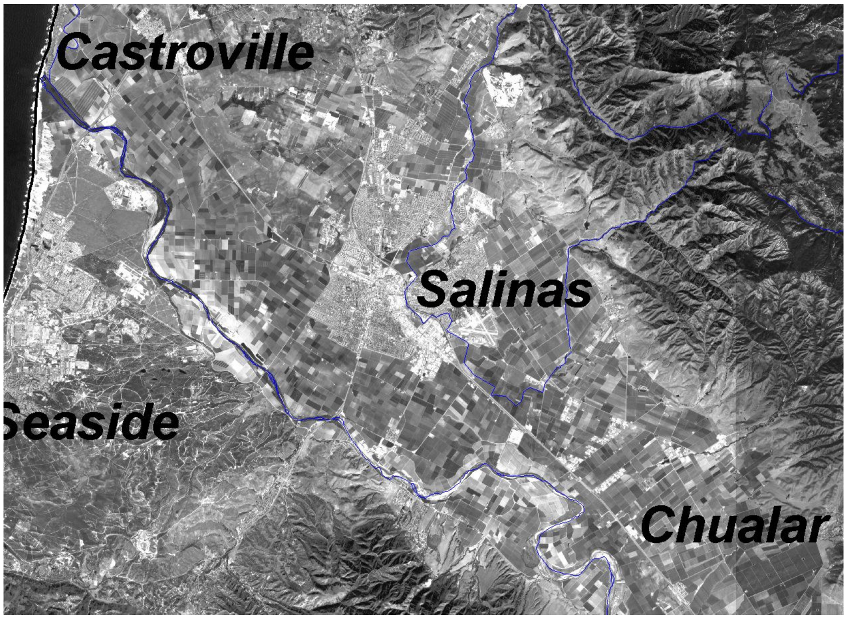


Figure 1 The Lower Salinas Watershed showing the intensive agricultural land use in the lower valley as well as the urban growth of the City of Salinas

There are many factors that have more immediate and long-lasting effects on beneficial uses than sediment. Physical modifications, as well as changes to the flow regime, that have been made over the last 100 or so years within the larger Salinas River/Elkhorn Slough watershed have had major impacts on the hydrologic and biologic functioning of the Salinas River/Elkhorn Slough watershed. Beneficial uses within the affected area have experienced a range of changes that are not clearly understood at the watershed scale. There have been a number of studies performed on the Salinas River/Elkhorn Slough Watershed but there is no comprehensive study of the watershed, its beneficial uses and how these uses might be impacted by the changes to the system and changes in water use and water quality within the watershed.

The result of our work has led us to two conclusions:

- The TMDL for sediment for the main stem of the Salinas River should be put on hold pending the outcome of a watershed assessment. If a watershed assessment can't be performed, staff recommends delisting the Salinas River for impairment due to sediment since there is not enough evidence to support the current listing.

- A watershed assessment of the Salinas River/Elkhorn Slough Watersheds should be performed in order to protect, enhance, maintain and improve water quality in a meaningful manner.

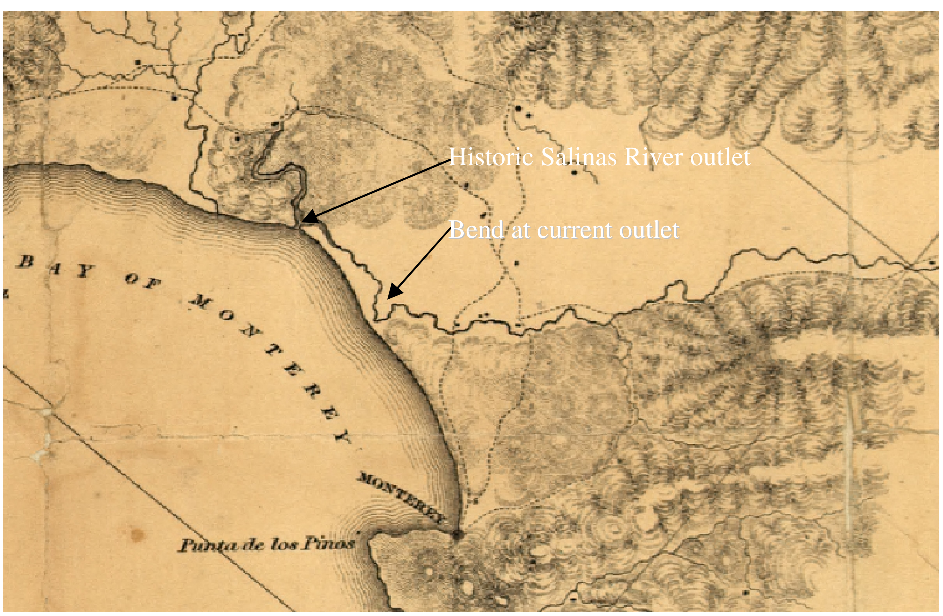
Elaborating on these two themes

  - Putting the TMDL on hold for the main stem of the Salinas River for impairment due to sediment. The reasons behind this recommendation are:

- Steelhead migration is the beneficial use that potentially could be affected by sediment.

  Elevated suspended sediment concentrations have been shown to affect salmonids by abrading their gills, by modifying behavior causing fish to avoid sediment-laden waters and by affecting sight feeding (outmigrating young only). Currently, specific research has not been done to establish the levels at which these effects occur for steelhead in the Salinas River Watershed.
- The original listing had no supporting documentation, data or rationale for why the river was added to the 303(d) list.
- There was a dramatic drop in the Salinas River Steelhead population between 1946 and 1951. The last good run was in 1946. There are a number of things that may have affected the steelhead population during this time period (e.g. drought, DDT and/or fertilizer use, hydromodification within the lower Salinas River)
- Sediment *transport* and *suspended sediment concentrations* have always been high in the Salinas River.
- Suspended sediment concentrations in the Salinas River are high relative to the rivers of the Pacific Northwest, Canada and Alaska where many of the studies on suspended sediment impacts to salmonids have been performed. Steelhead are adapted to local conditions and therefore extrapolating from studies performed in systems that are not like the Salinas River is hazardous at best. Also, the species used in many of the studies are not native to the Salinas River and therefore are not necessarily representative of species adapted to the river.
- There are many other factors that may have

Figure 2 Portion of General Maps and Surveys of California showing lower Salinas River with outlet at Elkhorn Slough (from Williamson, 1855)



contributed to the decline of the steelhead run in the Salinas River and sediment is not the primary cause of the steelhead's problems.

- The delay does not obviate the need for sediment control measures since other pollutants such as pesticides and nutrients attach to, and are transported with, sediment. Also, programs and policies such as the Ag Waiver Policy, the Stormwater Program and the various efforts associated with the Monterey Bay National Marine Sanctuary address sediment as one of a suite of constituents that need to be controlled.

Figure 3 View across the Lower Salinas Valley (Watson, et al., 2003)

- The second theme is that a watershed assessment should be performed. Protecting, enhancing, maintaining, and improving water quality requires a plan that has a broad watershed vision with a modular approach to implementation.

  The goals of the watershed assessment are to:

  - Establish biological endpoints for waterbodies within the assessment area. Biological endpoints for water quality assessment can include measures of the health of the Benthic Macroinvertebrates (BMI) community which include insects, worms and shellfish; it could include measures of fish population composition; or if interpreted more broadly it could include measures of the health of the riparian zone.
  - Identify areas that require special attention above and beyond existing efforts.
  - Identify past and present stressors on beneficial uses.
  - Provide a better understanding of the interactions of land use changes, hydromodifications, water quality and water use/management within the Salinas/Elkhorn Slough Watershed which is critical for making management decisions for maintaining and restoring beneficial uses within the context of working lands in the Salinas River Watershed.

Staff considered delisting the Salinas River for impairment due to sediment, but the case to be made is hampered by the lack of comprehensive monitoring data and lack of data on the effects of sediment on the local steelhead population. Any arguments must depend on anecdotal evidence and conclusions must be drawn based on incomplete information relating to the effects of sediment on locally adapted steelhead. We have taken a conservative approach towards the listing, although if a watershed assessment is not performed, staff would recommend delisting the main stem of the Salinas River because of lack of evidence of impairment due to sediment.

At this time we feel that it is appropriate to step back and gain the perspective that a watershed assessment can give so we can put sediment issues in their proper place. The proposed watershed assessment is meant to overcome some of the limits of our understanding in order to present a clearer picture of those things that are impacting beneficial uses, with an initial focus on steelhead. Eventually, we also hope to use the watershed assessment to go beyond just trying to fix "problem" waterbodies and look for opportunities to protect "high-quality" waterbodies.

Figure 4 View from the Santa Lucia Mountains
(Photo: Watson, et al., 2003)

2 Setting

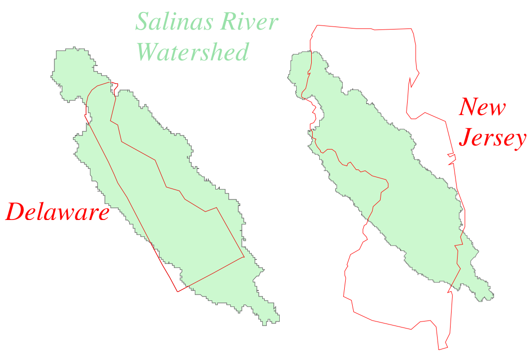


Figure 5 The Salinas Watershed area is approximately 4200 sq. miles - twice the size of Delaware and more than half the size of New Jersey.

The Salinas River Watershed is the largest watershed in the Central Coast Region. It is approximately 4200 square miles (2.7 million acres) in area comprising 37% of the Central Coast Region's total land area. As shown in Figure 5, the watershed is twice the size of the State of Delaware and more the half the size of the State of New Jersey.

The main stem of the Salinas River is a long low-gradient (less than 0.2% gradient at Atascadero Creek, less than 0.05% gradient at Spreckels), sand-bottomed river that historically has carried high sediment loads. Natural sediment production and movement is extremely variable and episodic due to the drought, fire, and flood sequence common to Mediterranean climates. The geology of the watershed, which includes the San Andreas Fault Zone along parts of its eastern boundary, also contributes to the high natural sediment loads within the system.

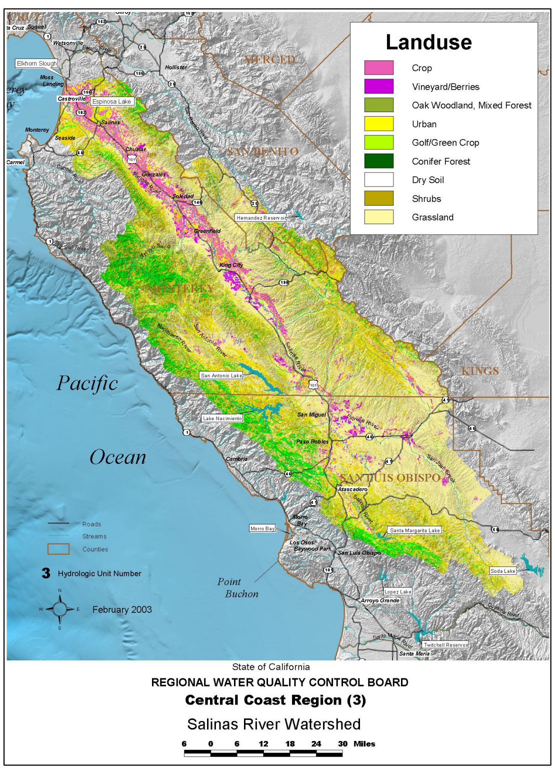


Figure 6 Salinas River Watershed Land Use

As can be seen in Table 1 and Figure 6 the majority of watershed is covered by more xeric landscapes represented by grasslands and shrub (typically chaparral). These occur in the rain shadow east of the Santa Lucia Mountains. The denser woodlands occur in the Santa Lucia Mountains on the western side of the watershed where winter storms can drop more the 55 inches of rain per year. Most of the row crops are located within the Salinas Valley north of King City along the Salinas Valley floor and on the adjacent terraces. These crops rely chiefly on groundwater for irrigation.

Table 1 Estimated Percent Land Use/Land Coverage

	Land Use/Land Cover	% of Watershed
1	Grassland/Some Irrigated Land	38.5%
2	Shrub	27.5%
3	Oak Woodland/Mixed Forest	12.3%
4	Mixed Conifer Forest/Montane	9.9%
5	Irrigated Agriculture/Row Crop	5.7%
6	Dryland Farming/Bare Soil	3.3%
7	Vineyard	1.3%
8	Urban	0.6%
9	Water	0.5%
10	Golf/Green Crop	0.3%

3 Analysis

3.1 The listing

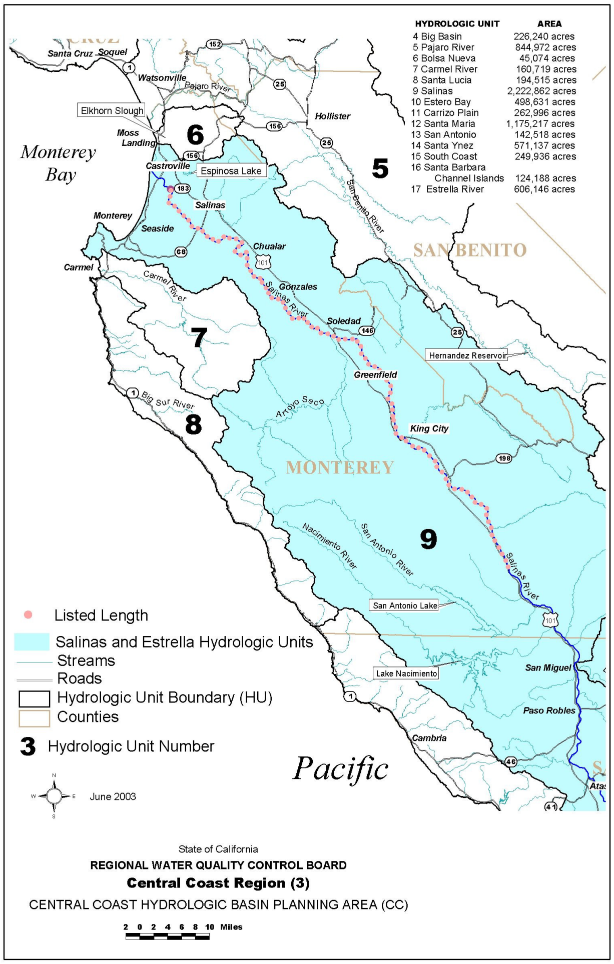


Figure 7 Listed Length of the Salinas River

The lower 90 miles of the main stem of the Salinas River is included on the Clean Water Act's 303(d) list of impaired waterbodies due to impairment caused by sedimentation/siltation. The listed section of the river begins, at its upstream end, near San Ardo, to the south, and ends at the Salinas River Lagoon. There is no apparent reason why just the lower 90 miles of the main stem was listed. The original listing did not have any documentation to support the listing or any information that explained which, or how, the beneficial uses were impacted by the sedimentation/siltation. Since there was no recent data about sediment movement within the Salinas River Watershed, we contracted with the Watershed Institute at the California State University at Monterey Bay to conduct a sediment source study in an attempt to define the existing conditions and to get an indication of what impacts sediment may be causing to beneficial uses in the main stem of the Salinas River and selected tributaries of the river. While it is the main stem of the Salinas River that is included on the 303(d) list, staff felt that some work in the tributaries was justified in order to begin to construct a current picture of sediment sources, sediment storage and sediment movement throughout the watershed.

3.1.1 Potential sediment problems in the main stem

After reviewing the list of Beneficial Uses associated with the main stem of the Salinas River, the beneficial use that may be most affected by sediment, or more properly by suspended sediment, is Migration (MIGR) as it applies to steelhead trout. The literature suggests that high-suspended sediment concentrations can affect salmonids by abrading their gills, by changing their behavior forcing them to seek cleaner water and by reducing sight distance thereby affecting their ability to find food. These effects are dependent on time of exposure and suspended sediment concentration. As suspended sediment concentration increases the same effects are noted at decreasing times of exposure. As will be discussed below, staff feels that existing studies may not be wholly applicable to steelhead within the Salinas River Watershed.

3.2 Salinas River Steelhead Population

Figure 8 Steelhead/Rainbow trout (Oncohynchus mykiss) yearling (1+ yrs) in Arroyo Seco River near the Santa Lucia Creek confluence. (Photo: Joel Casagrande, Aug 2002)

The U.S. Fish and Wildlife Service documented a dramatic decrease in the steelhead population of the Salinas River after 1946 (MCWRA, 2001). The last good run of steelhead was in 1946 when 3,600 fish were *caught (emphasis added)*. By 1951, the total population was estimated to be about 900 fish. As of 1965, the California Department of Fish and Game estimated the annual steelhead spawning run in the Salinas drainage at little more than about 500 fish, based on the observations of local field personnel (Titus, 2000). The latest estimates of the Salinas River steelhead population puts it at 50-100 fish (Hagar, 1996 and NOAA, 1996).

Although the continued decline of the steelhead population is cause for concern, it appears that a significant event, or combination of events, occurred in the mid- to late-1940's that severely impacted the steelhead's ability to spawn and reproduce. Some possible causes for the decline include four years of drought in the years 1947-50, the development of Moss Landing Harbor and the opening of the artificial mouth at Elkhorn Slough, and introduction of DDT for use in mosquito control and crop protection.

At this time, all possible explanations are speculative, but it is hoped that further study as part of an overall Salinas River/Elkhorn Slough watershed assessment would shed light on the cause of this dramatic decline.

The critical point in considering impacts to the steelhead fishery is that sediment is not a likely candidate for such a rapid decline in the steelhead population and that it is not a primary factor affecting the current steelhead population.

3.3 Sediment transport and suspended sediment concentrations have always been high in the Salinas River

This section attempts to tie together different sources of anecdotal and scientific evidence in order to show that the

The Portola Expedition in the Salinas Valley, September, 1769

They pushed along this strange river that would be up the horses' bellies sometimes, and would then go underground for several miles. The river was a trap of quicksand in places. Several horses and their precious packs were sucked out of sight before they could be rescued. There was plenty of grumbling and muttering as they made camp in willows that grew beside the niggardly autumn-sapped waterway.

… Disgruntled soldiers only sniffed and suggested (then name) the Rio del Chocolate, after the delectable luxury they could no longer have. At least it looked like chocolate when stirred up.

…After the next day's march to the west they reached a broad side valley where a clear cold stream bubbled through a canyon as if it would deny the time of year and make only a bad dream out of the golden heat-seared hills and lack of rain.

Anne B. Fisher, *The Salinas: Upside-down River*, 1942

Salinas River has always carried high sediment loads. We can only infer from the historical record how sediment moved through the Salinas River system prior to the time actual field measurements of sediment transport and concentration were made by the USGS between 1960-1984 and by the Salinas Sediment Study in 2001-2002.

The earliest written descriptions of the Salinas River are from the Portola Expedition of 1769. Some of their observations have been summarized in the sidebar "The Portola Expedition in the Salinas Valley, September, 1769." The description points out that the river was not continuous in the summer under natural conditions. The presence of quicksand indicates that there is upwelling of groundwater, so while the river went underground it probably wasn't very far from the surface. Also, quicksand indicates that the river had a sand bottom, as it does now. Lastly, the clear cold stream coming out of the Santa Lucia Mountains would have provided oversummering habitat for young steelhead.

A description of the flood of 1862 is given in the sidebar "The Flood of 1862 in the Salinas Valley." It indicates that the river could swallow acres of land and transport it towards the ocean during floods. The USGS estimates that the flood stage at Spreckels reached 31 ft during the flood of 1862. This is comparable to the flood level experienced during the

The Flood of 1862 in the Salinas Valley (when the whole state flooded)

The rain kept up its ceaseless tattoo, day after day, week after week, that spring of 1862. Tons of water poured from side canyons and valleys, sweeping all before it into the Salinas. The roaring yellow river went over its banks and kept rising. Stagecoaches could no longer get through. Soon the Salinas went wild and ate away acres of land like a hungry devil that would never be satisfied!

…Lives were lost as well as houses and stock. And still rain came down in the Salinas, thirty inches of it. Trouble swept like a heartless brown monster from the head of the river to its great brown mouth.

…David Jacks, the shrewd Scotch moneylender of Monterey, seemed to prosper with the spring flood in the Salinas. His Chualar Rancho had suffered little. In fact a fine layer of valuable silt had been laid down where once there had been cobblestones.

Anne B. Fisher, *The Salinas: Upside-down River*, 1942

Figure 9 Salinas River a few miles upstream of San Ardo: in the early 1900s,and in late 2002. (Old photo: courtesy of U.C.Berkeley, Recent photo: Fred Watson, Oct 3, 2002)

1995 flood with the caveat that the river had no levees to confine it in 1862. The highest instantaneous flow ever recorded for the Salinas River was 95,000 cubic feet per second that was recorded during the flood of 1995. Large floods have occurred in 1814-15, 1824-25, 1862, 1889-90, 1911, 1914, 1940-41, 1951-52, 1968-69, 1983-84, 1994-95 and 1997-98 (Anderson, 2000). The water year of 1997-98 had the highest recorded rainfall since 1861-62 (Anderson, 2000, pp.153-157).

Floods are the major player in sediment movement within the watershed. From the USGS sediment data discussed below, it can be inferred that sediment movement during flood years has always been high with correspondingly high suspended sediment concentrations.

The statement that the ranch at Chualar received a fresh layer of silt that covered cobblestones indicates that large amounts of sediment were transported during the flood.

Figure 9 shows the Salinas River upstream of San Ardo in the early 1910's and in 2002. The earlier photograph was probably taken after the flood of 1911 or 1914 although there is no date available for the photograph. The bottom photograph was taken in October, 2002 when the river was dominated by flows released from the Nacimiento Dam. The key features in these photographs are the extensive sand river bottom in the older photograph, and the well-developed riparian corridor in the more recent photograph. The sand bottom in the earlier photograph indicates that the river probably transported high sediment loads during the early 1900's when the steelhead population was still healthy. The increase in riparian vegetation shown in the 2002 photo provides greater bank stability than the bare banks of the earlier photo.

The reach shown in Figure 9 has experienced a drop in bed elevation of approximately 1 ft/decade based on an analysis by Watson, et al. (2003, pp. 112-117) of USGS gage flow data.at the Wunpost gage, which is located about 10 km downstream of the sediment-hungry dam releases coming from the Nacimiento and San Antonio Rivers. The summertime flows may be causing the long-term drop in the bed.

Figure 10 Buena Vista Bridge at Spreckels Sugar Plant (1935 Photo Courtesy MCARLM, Current photo from Wendi Newman, 2003)

Figure 10 shows another set of photos that compare pre-1946 and current bed conditions in the Salinas River. The two photos show that there has been little change in the river at the bridge crossing. Bed conditions in both pictures are similar and show that the river bed hasn't changed much between a time when steelhead were still plentiful and today when steelhead are almost non-existent. Again, the implication is that sediment is not a primary factor in the demise of the steelhead.

In his analysis of USGS flow data, Watson showed that since 1975 the bed elevation at Spreckels has fluctuated widely depending on flow conditions, but overall bed elevation has not changed since 1975. Summertime flows from the two reservoirs either never reach Spreckel's or they are not significant enough to be a factor in sediment movement at this site.

Data from the 1960's and 1970's indicate that sediment movement within the Salinas River is highly variable in time and in space. Data collected by the USGS at the Spreckels gage show that sixty-two percent (62%) of all of the sediment transported past Spreckels in a 10-year study period (1970-79) was transported in just 10 days in 1978 (Watson, et al, 2003). The 10 days represent 0.3% of all days for the 10-year study period. These tremendous loads appear to be associated with the Marble Cone fire that burned 177,866 acres of wilderness in July 1977. The Marble Cone fire was a

Figure 11 Sediment-laden Salinas River at confluence with the clear waters of the Arroyo Seco River March 8, 2001. (Photo by: Mark Angelo, Perspective Courtesy of CHP)

product of a number of natural events: heavy snowfall that broke many tree limbs, a drought in water years 1976 and 1977 and a lightning strike that started the fire.

Sediment concentrations are similarly variable. Seventeen of the top twenty suspended sediment concentrations during the 10-year study period at the USGS gage at Spreckels were measured during the 1978 water year, with concentrations ranging from 8,010 mg/L up to 24,000 mg/L.

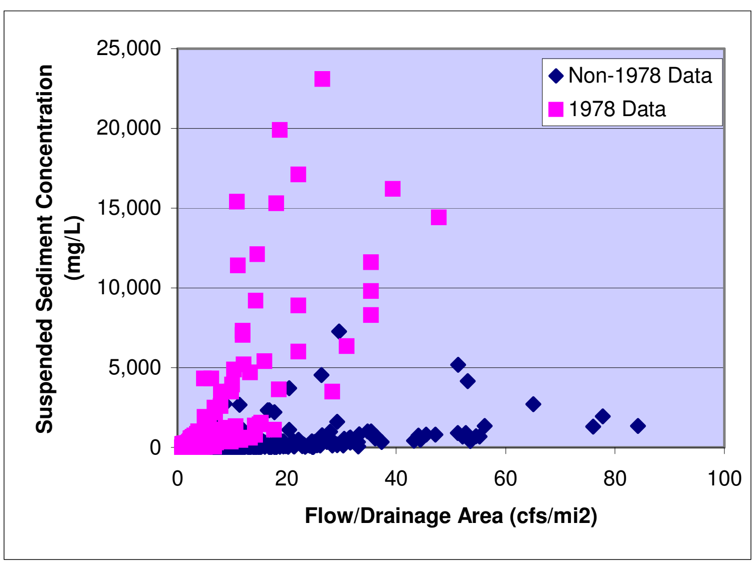


Figure 12 Arroyo Seco River - Comparison of Post-fire and non-fire related suspended sediment concentrations

Figure 12 compares suspended sediment data from the Arroyo Seco River from 1978, a year immediately following the Marble Cone Fire, and all other years (1960 – 1977, 1979-1984). The Marble Cone Fire affected a large portion of the Arroyo Seco River Watershed. It can be seen in the graph that suspended sediment concentrations are consistently lower in non-fire years, compared to concentrations at comparable flows during 1978, a post-fire year. The 1978 concentrations are a direct result of the Marble Cone Fire and they point out how natural conditions can lead to extremely high sediment transport and suspended sediment concentrations within the Salinas River Watershed.

It is unfortunate that we can’t translate what data we do have backwards in time without introducing a myriad of unknowns. Land use has gone from a landscape managed by the local indigenous population (fire to maintain grasslands) to heavy grazing use during the Spanish, Mexican and early American periods (1770's to 1860's). Wheat and barley were the main crops grown prior to the use of irrigation (1870's to 1910's). Irrigated agriculture increased dramatically in the 1920's, with the introduction of lettuce and other row crops, and has continued to grow to cover 180,000 acres in Monterey County.

What can be said is that sediment transport in the main stem has always been high, with a riverbed consisting primarily of sand-sized sediment. The river has experienced periodic flooding throughout its history that would move large volumes of sediment, would cause fluctuations in bed elevation and, prior to levee construction along the river, would inundate floodplains and drop part of its sediment there, creating slow, clear water havens for migrating steelhead.

3.4 Steelhead Studies

The studies done to date on the effects of suspended sediment concentrations on migrating salmonids cover a range of possible effects. It is difficult to extrapolate the results of these studies to the steelhead fishery in the Salinas River because the studies have been carried out on salmonids from Northern California, the Pacific Northwest, Canada and Alaska that experience much lower natural suspended sediment concentrations than the Salinas River experiences. Titus (2000) states that "relatively little consolidated effort has been expended on determining the status and factors which affect steelhead stocks south of San Francisco Bay."

Also, the majority of the studies that have been performed have been on species other than steelhead and their response to suspended sediment concentrations may vary enough to make extrapolation of the data risky at best. The steelhead represented in these studies are genetically distinct from the South Central California Coast Evolutionary Significant Unit and therefore may be adapted to different natural suspended sediment concentrations.

Shapovalov and Taft (1954, p.31) state that "we must constantly keep in mind that variation, i.e., deviation from the norm, is one of the most marked characteristics of animal life. And of the vertebrates, the trouts are among the most variable of all. Further, of the trouts the steelhead is one of the more variable forms." This high variability is what allows the steelhead to survive in systems that are less than optimal, such as the Salinas River Watershed.

3.4.1.1 Migrating Salmonid Response to Suspended Sediment Concentration

Various sources indicate that salmonid behavior or health are affected by suspended sediment concentrations that range from 100 parts per million (mg/L) to 31,000 parts per million (mg/L) (see Table 2). Duration of exposure should also be considered when considering the effects of suspended sediment on salmonids. Newcombe (1997) has

Table 2 Sediment Concentration Levels and Possible Effects on Migrating Salmonids

Species	Life Stage	Effect	Concentration (mg/L)	Source	Notes
Coho	Smolts	Reduced or Ceased Feeding	100 mg/L and >300 mg/L	Birtwell, I. 1999. p.16.	Univ. of Washington
Sockeye	Adult	Secondary Stress	1,500 (9 days) 500 (15 days)	Birtwell, I. 1999. p.17	Fraser River, Canada
Steelhead	??	Abrasion, thickening, and fusion of gill filaments	3,000	USFWS-1, 1986, p. 12	
Sockeye	Under-yearlings	Gill Trauma	3,148 (96 hour)	Birtwell, I. 1999. p.17.	Fraser River, Canada
Salmonid	Adult Upstream Migration	May cease upstream movement	4,000	USFWS-2, 1986, p. 17	
Sockeye	Smolts	Slight impairment to osmorequlatory capacity.	14,407	Birtwell, I. 1999. p.17	Fraser River, Canada
Sockeye	Juvenile	Lethal	17,600 (LC50 – 96 hour)	Birtwell, I. 1999. p. 13	Fraser River, Canada - Lab Tests
Coho	??	Lethal	@7Deg C – 22,700 (LC50-96 hour) @18Deg C – 7,000-8,100 (LC50-96 hour)	Birtwell, I. 1999, p. 14	Fraser River, Canada - Lab Tests

Species	Life Stage	Effect	Concentration (mg/L)	Source	Notes
Chinook	Juvenile	Lethal	31,000 (LC50-96 hour)	Birtwell, I. 1999. p. 13	Fraser River, Canada - Lab Tests

developed models that estimate the severity of ill effects in fishes associated with excess suspended sediment. In general, as concentration increases, the same ill effects are developed at successively shorter periods of exposure.

The problem with much of the information on the impacts of sediment to salmonids is that it originates from areas distinctly different from the Salinas River Watershed. The Salinas River is a long (40 miles to the Arroyo Seco River, 101 miles to the San Antonio River, 105 miles to the Nacimiento River and 130 miles to Paso Robles Creek) low-gradient sand-bottomed river with highly variable flows. Naturally high suspended-sediment loads are associated with high-flow events. Some of the more relevant work on sediment –induced stress on salmonids has come out of Canada, especially from C.P. Newcombe with his severity of ill effects matrix which relates suspended sediment concentrations and duration of exposure to various effects on salmonids. While this information is useful on a conceptual basis, it is difficult to apply the method to the Salinas River without some trepidation. The steelhead in the Salinas River have evolved in a system with intermittent occurrences of high concentrations of sediment, therefore the concentrations which cause ill effects could be markedly different than those concentrations reported by Newcombe.

An example of how variable the response to sediment can be between species is illustrated by the suspended sediment concentration where 50% of the test fish die in a 4-day test, known as the LC_{50} – 96 hour. As shown in Table 2, the LC_{50} –96 hour for juvenile coho salmon is 17,600 ppm and for juvenile Chinook salmon it is 31,000 ppm. The LC_{50} – 96 hour for juvenile coho salmon is a little more than half the value for juvenile Chinook salmon. If the concentration for lethality can be that different for two species from the same watershed, it can be assumed that there could be similar or greater variability between the effects levels for other behavioral and physical responses between Salinas River steelhead and other species from systems that are very different than the Salinas River.

3.4.2 A comparison of the Salinas River and the Eel River

A comparison of the suspended sediment concentrations between the Salinas River and the Eel River was made to show how sediment concentrations in the Salinas River are significantly greater than the rivers of the northwest where most of the research of suspended sediment impacts to salmonids has been performed. The Eel River was selected to represent the northern systems because it is noted for it's tremendous sediment production and it's once prolific steelhead fishery. The Eel River "holds the record for the greatest average annual suspended load for any stream of its drainage area or larger in the United States; it exceeds both the Colorado and the Mississippi in this respect! In tons of sediment per square mile of drainage basin, the Eel yields 4 times as much as the Colorado and 15 times as much as the Mississippi" (Norris, 1990, p. 364).

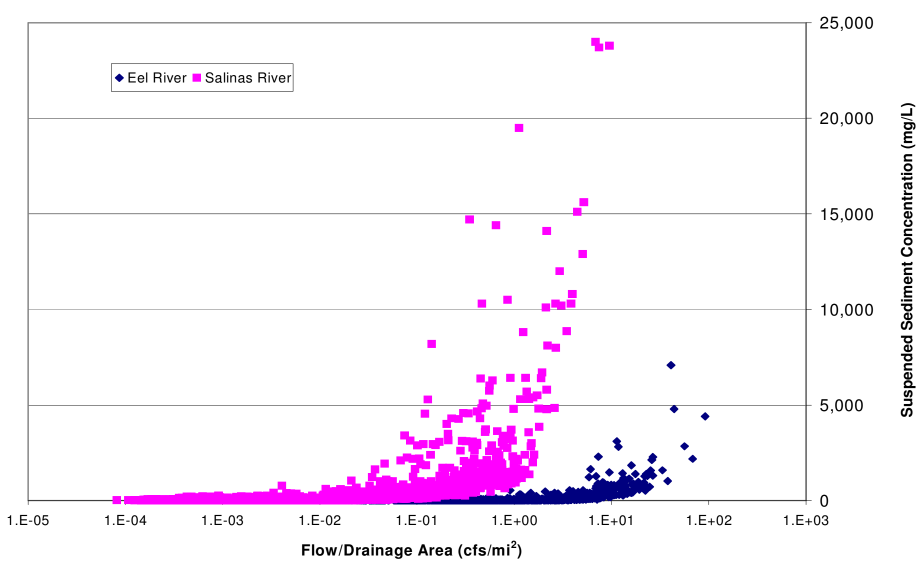


Figure 13 Suspended Sediment Concentration Comparison between the Salinas River at Spreckels (1970-1979) and the Eel River above Dos Rios (1960-1965)

The adult steelhead spawning population for the Eel River was estimated by California Department of Fish and Game to be 82,000 during the mid-1960's (Busby, 1996, p. 127) during the period when the sediment data was gathered.

The period of record for the sediment data includes major flow/sediment transport events for both rivers. The 1964 Eel River flood was captured in this dataset as well as the post-Marble Cone fire flood flows of March 1978 for the Salinas River.

Figure 13 illustrates the difference in suspended sediment concentrations between these northern systems as represented by the Eel River and the Salinas River. In order to facilitate comparison of the data, flow data was normalized by dividing mean daily flow measurements by the contributing watershed area. The Salinas River experiences suspended sediment concentrations that are never approached in the Eel River. The highest concentrations in the Salinas River are associated with the natural conditions of drought, fire and flood that are expected in Mediterranean climates. This comparison calls into question the validity of using criteria for suspended sediment concentrations that are derived from watersheds that differ significantly in their hydrology and suspended sediment concentrations from the Salinas River. Local data of the effects of suspended sediment to steelhead should be developed in order to place suspended sediment in its proper place among the stressors affecting steelhead in the Salinas River Watershed.

3.5 Steelhead are Locally Adapted

The South-Central California Coast "steelhead Evolutionarily Significant Unit (ESU) occupies rivers from the Pajaro River, Santa Cruz County to (but not including) the Santa Maria River. The steelhead within the South-Central California Coast ESU are distinct from other ESUs by virtue of unique characteristics of their DNA. Mitochondrial DNA data provide evidence for a genetic transition in the vicinity of Monterey Bay. Both mtDNA and allozyme data show ***large*** (emphasis added) genetic differences between populations in this area, but the data do not provide a clear picture of population structure" (NOAA, 1996, p. 65)

Within the ESU, the Salinas River Basin is "ecologically distinct from the populations in the Big Sur area and San Luis Obispo County, and thus, its degradation affects spatial structure and diversity of the ESU" (NOAA, 2003, p. 104) The unique genetic make-up of the South-Central California Coast steelhead, as well as the Salinas River steelhead, is an indication that they have adapted to local conditions.

Again, the point is that the steelhead in the Salinas River have adapted to local environmental conditions that are far different than the environmental conditions in Northern California and further north. To extrapolate data from studies performed from more northerly regions to the South-Central Coast ESU is not appropriate.

3.6 Issues other than Sediment that impact Steelhead

During the course of the sediment study, it became apparent that there are numerous issues other than sediment within the Salinas River system that could impact steelhead directly and/or indirectly. The steelhead population in the Salinas River has experienced two documented periods of decline. The first was a dramatic decline in the years 1946-1951 and the second has been a long-term decline since 1951.

As discussed in section 3.2, there was a dramatic decrease in the steelhead population of the Salinas River between 1946 and 1951. Since 1951 the steelhead population has declined from an estimated spawning population of 900 fish to 1996 estimates that put the spawning population at 50-100 fish.

There may be a number of factors other than sediment that caused the population decline in 1946-1951 and another set of factors other than sediment that have caused the continued decline of the Salinas River steelhead population since 1951. These factors are not necessarily the same for the different phases of decline.

The *dramatic* population decline in 1946-1951 may be understood by a single factor, or combination of factors, that lasted for four years or more. The maximum lifespan of a steelhead is 7 years, but most fish returning to spawn are 3- or 4-year olds. If a detrimental change to the system lasted at least 4 –7 years, a run could be significantly reduced in a relatively short period of time.

The *long-term* decline in population may be attributed to dramatic changes (e.g. Dam construction and water regulation) as well as more long-term changes (e.g. levee construction, groundwater withdrawal) that may have begun prior to the 1946-1951 decline.

3.6.1 Dramatic Steelhead Decline (1946-1951)

There are a number of factors that could have caused the dramatic decline in steelhead population. The extreme drought of 1947-1950 is a primary suspect. The construction of artificial mouth at Elkhorn Slough that was installed to provide access to the newly constructed Moss Landing Harbor and associated improvements may also come into play as well as increased use of DDT and synthetic fertilizers in the post-war years. Also, in the early 1940's the City of Salinas added a second wastewater treatment plant that discharged directly to the Salinas River near Spreckels which had a direct impact to water quality in the Lower Salinas River.

3.6.1.1 1947-1951 Drought

According to NOAA (2003), in Kelly and Dettman's best professional opinion, 30 days of flows greater than 200 cfs at Spreckel's gage during the migration season are required for adult steelhead to migrate upstream to the Arroyo Seco River. Using 200 cfs as a minimum flow criteria, the drought of 1947-1951 is the longest continuous drought in the Salinas Valley since 1930, when flow measurements at Spreckels were begun. Figure 14 displays the number of days that exceed 200 cfs for water years 1940 through 1955. It can be seen that for the five continuous years of 1947-1951 the number of days that flow exceeded 200 cfs never reached 30. Five years of drought could have a devastating effect on the steelhead population and may be reason enough by itself to account for the decline of 1946-1951.

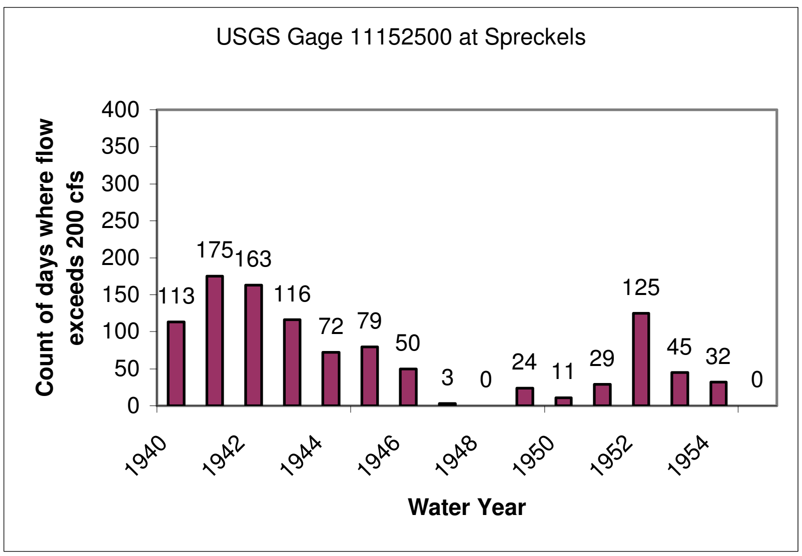


Figure 14 Number of days when flow exceeds 200 cfs at USGS Gage 1152500 at Spreckels

It should also be noted that heavy groundwater pumping for irrigation during these years exacerbated the effects of the drought on the river's flow.

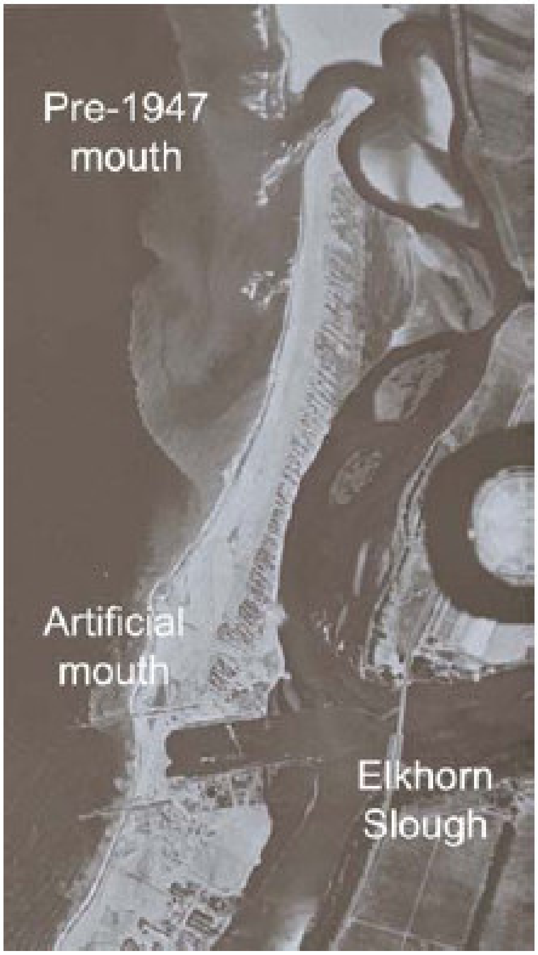


Figure 15 1946 aerial photo showing construction of new artificial Slough mouth in line with main channel, and smaller natural mouth to the north [ESNERR collection] (Elkhorn Slough, Website Report-1)

3.6.1.2 Construction of artificial mouth at Elkhorn Slough

The construction of the artificial mouth at Elkhorn Slough may have affected the steelhead population. The Army Corps of Engineers breached the sand bar at Elkhorn Slough in 1947 in order to create access to Moss Landing Harbor. "Prior to 1947, the Slough was an estuary with sluggish tidal flow entering from a mouth a the Salinas river. This small opening was sometimes obscured by a sand bar for months at a time, and even when open let only relatively small volumes of seawater into the Slough system. In 1946, the Army Corps of Engineers built jetties directly west of the main channel of the Slough, and in 1947, they breached the shoreline dunes and dredged a wide, deep channel to permit entry of boats into the newly created Moss Landing Harbor " (ESNERR, Website Report-1). While this is not conclusive evidence that the steelhead decline was precipitated by the work done by the Army Corps of Engineers, it is worth investigating since the work was completed coincident with the dramatic decline of the Salinas River steelhead population.

Other modifications that could have contributed to the decline of the Salinas River steelhead run are the tide gates located at Portrero Road on the old Salinas River and the weir gate that was installed between the Salinas River Lagoon and the Old Salinas River, although the dates of installation for these structures have not been identified yet, although the weir gate may have been installed as early as 1908 (Silberstein, 1989).

These modifications could affect steelhead by increasing the salinity of the estuarine environment where they undergo the transformation from freshwater to saltwater fish. Also, the tide gates and the weir gate could block upstream and downstream migration.

3.6.1.3 DDT and Synthetic Fertilizers

A discussion of DDT and synthetic fertilizers are included here because the increase in their use coincided with the dramatic decline in the steelhead population. No data have been collected on either the level of use of

DDT or its effect on steelhead within the Salinas Valley, but it is known that mosquito abatement spraying in Monterey County using DDT was conducted between the mid- to late 1940's until 1957 when Monterey County decided that aquatic use of DDT would be discontinued. It should be noted that "in 1957, as a matter of policy, the Forest Service, U.S. Department of Agriculture (USDA), prohibited the spraying of DDT in specified protective strips around aquatic areas on lands under its jurisdiction" (EPA, Website-1)

Although we don't have specific data about DDT use in the Salinas Valley during the 1946-1951 time-frame, EPA states that after 1945, agricultural and commercial usage of DDT became widespread in the U.S. (EPA, Website-1).

Staff has not investigated the effects of DDT on steelhead yet, but it is possible that when it was in use it could have had both direct and indirect effects on steelhead.

The use of synthetic fertilizers increased greatly after WWII. The use patterns and possible effects of these fertilizers on steelhead have not yet been investigated, but it is another factor to consider.

3.6.1.4 City of Salinas Wastewater Treatment Plants

The lower Salinas River and the Salinas River Lagoon were affected for years by discharges from two City of Salinas wastewater treatment plant. Areas that may have provided habitat for steelhead prior to their escape to the ocean experienced algal blooms and low dissolved oxygen levels that would have rendered the habitat unsuitable for steelhead.

Two wastewater treatment plants that serv the City of Salinas used to discharge directly to the Salinas River. Treatment Plant 1, which began operation in 1930, discharged to the Salinas River just downstream of Davis Road (river mile 10). Treatment Plant 2, which began operation in 1943, discharged to the Salinas River downstream of Spreckels (river mile 13). The plants' discharges were diverted to a regional facility in 1990, and are no longer discharged to the Salinas River.

During the 1960's, the Department of Water Resources conducted an investigation of the Lower Salinas River (DWR, 1965). The report's description of the river during low flow conditions is depressing at best. For 10 miles downstream of Treatment Plant 2, the stream was impacted by the wastewater discharge. Close to the plants "dissolved oxygen is at a minimum often going down to zero. Hydrogen sulfide and other foul odors are continuously giving off and bottom sludge deposits are black, septic and under active decomposition" (DWR, 1965, p. 8). Further downstream conditions improved, but algal blooms were prevalent causing wide fluctuations in dissolved oxygen levels (at one site 13.3 ppm day, 1 ppm night).

The Salinas River Lagoon had similar problems. "During low flow conditions the lagoon reflects that quality of the Salinas River with the exception of the numerous periods when the lagoon is radically affected by the incursion of highly mineralized seawater.

"The appearance of the lagoon at low flow is distasteful. Algal blooms always are present, ranging in color from green to brown. Bottom deposits are black and smelly" (DWR, 1965, p. 29). Large fluctuations in diurnal dissolved oxygen values were also noted, with low values reaching 3.1 ppm.

3.6.2 Long-term Steelhead Decline (1951-present)

The long-term decline of the steelhead in the Salinas River Watershed is probably associated with a number of factors. Levee construction, major dam construction and operation, groundwater withdrawal and numerous physical barriers to upstream movement have combined to make life hard for steelhead in the Salinas River Watershed. Some of these factors are discussed below while others are identified as potential causes of steelhead population decline.

3.6.2.1 Levees – loss of connection to flood plain

Loss of connection to the floodplain by construction of levees is the one of the primary issues associated with elevated suspended sediment concentrations. Levees have been constructed along much of the lower river in order to protect valuable farmland and urban areas from floodwaters. Levees disconnect the river from its natural floodplain where the river would normally drop some of its sediment load and where slack water areas would provide off-channel resting areas for adult steelhead during their upstream and downstream migration and for juveniles during their downstream migration to the ocean. As the water drops its sediment load in the floodplain, total suspended sediment in the water decreases dramatically, providing a haven for steelhead from the main channel with its higher suspended sediment loads. These slack water areas are also sources of food for out-migrating juveniles. The value of these off-channel areas has been demonstrated in the Cosumnes River (http://www.cosumnes.org/project.htm) and on the Yolo Bypass (http://www.calacademy.org/calwild/fall99/flood.htm).

Levees also cause the river depth and velocity to increase during high flows, relative to the same unconfined flow. This is because the levees confine the river to a much smaller cross-sectional area. Higher velocity flows may increase suspended sediment concentrations due to increased energy. Increased depth and velocity can increase shear on the riverbed increasing the movement and suspension of bed material. Increased velocities can also make migration difficult by increasing travel time and the energy expended.

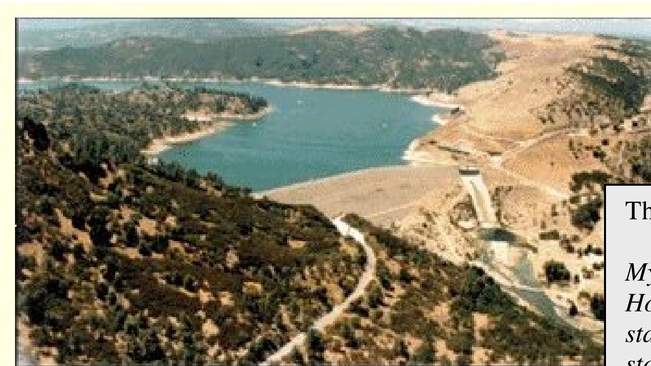


Figure 16 Nacimiento Dam (from SVWC Website)

The early 1900's in the Salinas

My Grandparents' house was just above the "Big Hole" on the Nacimiento River where the dam now stands. I remember my grandfather telling of stories of dropping dynamite into the Big Hole and stunning fish, but he didn't talk of getting fish that large. They must have been steelhead.

Adapted from Harold A. Franklin, *Steelhead and Salmon Migrations in the Salinas River (personal history, unpublished)*, 1999

3.6.2.2 Major Dams as barriers

Some of the best spawning and rearing habitat in the Salinas River Watershed is located behind the Nacimiento Dam (1957) and the San Antonio Dam (1965). Less valuable habitat is located behind the Salinas Dam (1942) on the main stem. This habitat is now inaccessible to the steelhead of the Salinas River. Recently, few steelhead have been seen in the river below the Nacimiento Dam.

During the fieldwork that was performed as part of the studies by the Watershed Institute, a significant rainbow trout/remnant steelhead fishery was observed above the Nacimiento River Dam.

3.6.3 Dam Operation – Change in Flow Regime

The Nacimiento and San Antonio Dams were built to control floods and to replenish groundwater supplies depleted by pumping. By capturing the winter flows and releasing them in the summer the dams have dramatically changed the flow regime of the Salinas River.

How these operational objectives are played out in changes in flow regimes can be seen graphically in Figure 17 and Figure 18 (Note the differing scales for the flow). Figure 17 shows natural flows in the Nacimiento River upstream of the dam. The flow pattern is typical of a Mediterranean

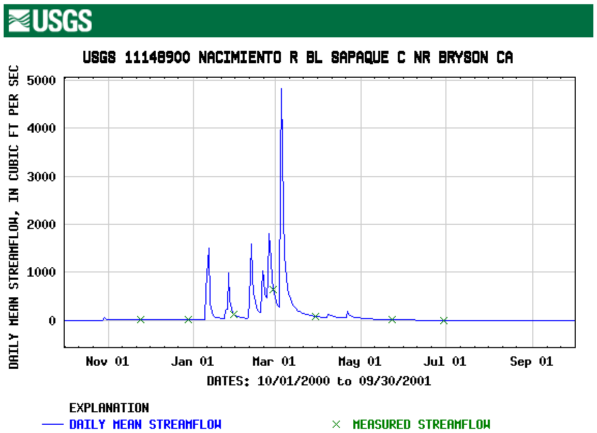


Figure 17 Natural Flow above Nacimiento Dam for Water Year 2001 (USGS Website-1)

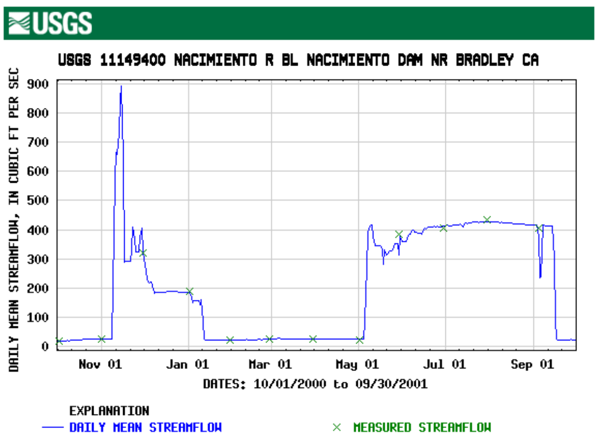


Figure 18 Regulated Flow below Nacimiento Dam for Water Year 2001 (USGS Website-1)

climate where storms pass through during the winter months and there is little rainfall in other months. Figure 18 shows how these natural flows are turned on their head by the dam operation. The natural flows are captured completely only to be released at a more controlled pace during the dry months. Peak flows are reduced by 5-fold.

Potential effects of these changes include:

- Reducing the number and frequency of certain size flow events in the main stem that in turn may affect sediment transport through the system,
- Possible delay of the sand bar breaching at the mouth of the river that can delay the arrival of spawning steelhead trout to their spawning grounds,
- An increase in summer flows that has unknown effects on the ecology of the system.

3.6.4 Extraction of groundwater

Groundwater withdrawals have lowered the water table along much of the river's length. This has affected how the river responds to early season flows. Depending on the year and the storm patterns, it can take a number of storms before the lower river connects to the ocean.

During our work in the tributaries to the Salinas River it became apparent that many of the tributaries to the Salinas River have reduced summer flows that, in part, appear to be due to local groundwater extraction. Flow, or lack thereof, is one of the critical issues for protection of beneficial uses in our smaller streams.

3.6.4.1 Draining/conversion of delta

The area between the Salinas River and the Elkhorn Slough was once full of sloughs and wetlands. This area has largely been drained through the use of tile drains, pumps and straightening of the sloughs in order to make the area farmable. This area would have served as a place where smolts would acclimatize to the more saline ocean environment themselves prior to heading into the ocean. The loss of these areas may have contributed to the long-term decline of the steelhead population in the Salinas River.

3.6.4.2 Other Issues

Other issues that may negatively affect steelhead are:

- Barriers to migration other than the major dams mentioned above. These are road crossings, culverts and smaller dams located on tributaries to the mainstem of the Salinas River.
- Planting of steelhead from other ESUs that may have affected the genetic composition of the Salinas River steelhead.
- Competition from non-native species that have been introduced into the Salinas River Watershed.

4 Highlights of the Sediment Study

A synopsis of some of the findings from the Salinas Valley Sediment Sources Study performed by the Watershed Institute at California State University, Monterey Bay is outlined below. The full report can be found at http://science.csumb.edu/~ccows/ under Salinas TMDL Project – Salinas Sediment.

Variability is the only constant when trying to figure out where sediment originates and where it is transported and when all of this happens. That being said, there are some general conclusions that can be drawn from the field work and analyses that have been done to date.

Natural sources of sediment can be significant, especially along the San Andreas fault zone (see Figure 19). One area at the head of Pancho Rico Creek is suspected of a being source of unusually high suspended sediment concentrations.

Figure
in Panc
2003)

Sediment production from agriculture can be significant and suspended sediment concentrations can range over a three orders of magnitude during a single event. Mean concentrations as high as 35,000 mg/L have been measured directly from fields. Measured concentrations are highly variable between fields and between farms. Soil texture, cropping patterns, irrigation methods and slope are factors that affect sediment production and concentrations. Many farms recycle their sediment production by capturing it in sediment basins and redistributing it back to the fields.

These high concentrations may manifest themselves as elevated concentrations (measured concentrations of 1,000 mg/L to 3,500 mg/L) in the main stem of the Salinas. The analysis of the source of the elevated concentrations in the main stem is complicated by various inputs upstream of the monitoring site where the data were collected and the unknown contribution of in-stream sources. The impacts of these concentrations are uncertain as discussed in Section 3.4

It should be noted that high suspended sediment concentrations (ranging up to 24,000 mg/l) were found for samples taken on the rising limb of the hydrograph for an early season storm. They appear to have natural causes and have been attributed to major bed mobilization during the rising limb of the largest hydrograph in 3 years (Watson, 2003b).

The sediment and habitat assessment work on the tributaries provided us with two useful insights. On a practical level, access to sites on private lands is critical. This was a limiting factor in our ability to understand the condition of some of the tributaries. A more critical observation was the lack of water in many of the tributaries during the critical summer months. It appears that many of the tributaries may have water at intermediate elevations with dry upper reaches and dry lower reaches. Flow occurs where bedrock is close to the surface and disappears into alluvial deposits. Understanding where flow occurs is a critical piece of information in managing for water quality.

5 Watershed Assessment

Given all of the uncertain in the how the Salinas River system functions, it is felt that a watershed assessment would provide the proper perspective for moving forward with water quality improvements. The ultimate goals of the watershed assessment are to:

- Establish biological endpoints for waterbodies within the assessment area.
- Identify areas that require special attention above and beyond existing efforts.
- Identify past and present stressors on beneficial uses.

A brief description of each of these goals and how they will help us manage water quality follows.

5.1 Establish biological endpoints for waterbodies within the assessment area.

The use of biological endpoints as indicators of water quality has been used in some states to provide a primary assessment tool for judging the health of waterbodies. Biological endpoints, also known as biocriteria, can be a combination of macroinvertebrate, fish and plant diversity and/or abundance and riparian health. Physical and chemical characteristics that can affect biocriteria need to be identified in order to protect those biological endpoints that have been deemed appropriate for the waterbody in question.

We want to develop biological endpoints for the waterbodies in the Salinas/Elkhorn Slough Watershed. Some states, such as Ohio, have stratified their waterbodies into modified or unmodified groups in order to better define what the expected biological endpoint would be for each waterbody. We want to see if this type of approach makes sense for the waterbodies within the Salinas/Elkhorn Slough Watershed.

Many of the waterbodies within the Salinas/Elkhorn Slough Watershed have been modified directly by physical changes to the system such as tide gates, levees, channelization, dams, and surface water management, and indirectly by groundwater withdrawal. We need a clear definition of the beneficial uses associated with these modified waterbodies in order to establish viable biological endpoints that will inform our management decisions. These waterbodies may be modified to such an extent that they will no longer support the full suite of organisms that they once supported. We need to be clear about where these waterbodies are, how they have been modified and what we expect them to look like when we have attained water quality standards.

The same approach needs to be applied to "unmodified" waterbodies within the watershed. "Unmodified" is in quotes because all of our most intact waterbodies have experienced some level of management whether it is associated with fish plants, minimal road development or some other factor that has impacted the waterbody in some way.

Once an understanding of the biological endpoints is developed, management decisions and measures of success can be formed that compliment each other. Our current biological beneficial use designations are not detailed enough, and as such, require interpretation by staff in order to understand what may be impacting a particular beneficial use. With a clear endpoint defined, continuity and consistency can be maintained among staff and through time.

5.2 Identify areas that require special attention above and beyond current efforts.

We want to identify waterbodies where there are opportunities to improve or change current management strategies or implement new ones in order to enhance or protect beneficial uses. It is anticipated that these management efforts will not be solely water quality related. Management of water levels, varying existing flow regimes downstream of dams and removal or redesign of certain hydromodifications may all be part of a comprehensive approach to restoring, maintaining and enhancing beneficial uses. These types of efforts will require coordination with multiple agencies and landowners. It is recognized that there are many efforts that have already been initiated to assess water quality and to implement practices within the assessment area and we would work within these existing efforts.

To protect existing high quality waters requires a special effort to identify those high quality waters that do not have adequate policies in place to ensure that these waters remain high quality waters. We feel that this work is an essential component to a comprehensive approach to restoring, maintaining, enhancing and protecting water quality and beneficial uses.

As part of the TMDL work within the Salinas River Watershed, we have begun to form a Technical Advisory Committee to work with the Regional Board in creating effective TMDLs. Currently the committee membership includes researchers from CSUMB and UCSC, landowners from the valley, representatives from the NRCS, the local RCD, the MCWRA and the City of Salinas as well as Region 3 personnel. We hope to expand the committee to include more landowners and personnel from the California Department of Fish and Game and NOAA Fisheries.

5.3 Identify past and current stressors on beneficial uses

We need to identify all of the stressors that have in the past affected, or are currently affecting, beneficial uses in order to better inform our efforts when making decisions for the management of water quality. As discussed in the previous sections concerning sediment impacts to steelhead in the main stem of the Salinas River, there are a number of factors that affect beneficial uses within the watershed that require better understanding. These include the physical and chemical properties of the water, hydromodifications, land use management, surface water management and ground water withdrawals as well as the seasonal, annual and spatial variation of weather patterns within the watershed. All of these factors interact and impact water quality in some way. We want to establish a baseline of knowledge on how the Salinas/Elkhorn Slough system functions given the changes that it has experienced in the past and that it is currently experiencing so we can make intelligent management decisions in the future.

Also, if the watershed assessment identifies suspended sediment concentration as a critical factor affecting steelhead, then specific studies should be undertaken to determine the concentrations that affect the local steelhead population. We should get watershed level data, or at least region specific data from a similar watershed, than is more relevant for the Salinas River Watershed than the existing body of data.

6 Conclusions

To reiterate what we proposed in Section 1 of this document staff believes that:

1. Put the Salinas Sediment TMDL on hold until a Watershed Assessment can be completed.
2. If no Watershed Assessment is performed, remove the mainstem of the Salinas River from the 303(d) list of impaired waters, since there is not enough data to justify the current listing.
3. A Watershed Assessment should be performed in order to better understand how the Salinas River Watershed system operates and to better define beneficial uses within the various waterbodies within the watershed.
4. As part of the Watershed Assessment, the issues associated with steelhead survival should be reviewed to ensure that suspended sediment is, or is not, a significant issue. At this point, it does not appear to be a significant issue.

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