Swanson Hydrology & Geomorphology

115 Limekiln Street Santa Cruz, California USA 95060
phone 831-427-0288 / fax 427-0472

Draft Report

Steelhead Restoration Planning Project

for the

Morro Bay Watershed

submitted to

Coastal San Luis Resource Conservation District

by

John Dvorsky, Swanson Hydrology & Geomorphology

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CHAPTER 1 – INTRODUCTION

In October of 2000, Governor Gray Davis approved the Morro Bay National Estuary Program's Comprehensive Conservation and Management Plan (CCMP) for Morro Bay and its watershed that includes the Chorro and Los Osos Creek drainages. In January 2001, the CCMP was approved by the U.S. Environmental Protection Agency, setting the stage for restoration and enhancement of the Morro Bay watershed. The CCMP is a comprehensive, watershed-based document that aims to protect and restore natural functions of the estuary through sound science and a set of action plans designed to tackle the sources of estuary degradation. The developers of the CCMP were forward-thinking in their desire to address issues such as sedimentation, streamflow, and habitat protection throughout the watershed rather than implementing a program that focuses solely on the condition and enhancement of the estuary.

The action plans in the CCMP were grouped into nine primary categories including cross-cutting actions, sedimentation, bacteria, nutrients, freshwater flow, heavy metals and toxics, habitat, steelhead, and public outreach and education. This report specifically addresses the first item in the Steelhead action plan. This action, titled STL-1 seeks to:

> *"Implement agency decision-making in the Morro Bay watershed consistent with steelhead trout recovery goals, and support the implementation of the National Marine Fisheries Service (NMFS) Recovery Plan."*

This report, titled the Steelhead Restoration Planning Project for the Morro Bay Watershed, along with an existing data summary, stream inventory reports for Chorro, Dairy, and Pennington Creeks, and a steelhead distribution and abundance report, is being prepared to forward the goal of enhancing and restoring steelhead populations in the Morro Bay watershed. To accomplish this goal, the Restoration Plan will analyze existing data to determine the critical unmet habitat needs (such as lack of pools, lack of cover, elevated temperatures) for steelhead in the watershed, and also identify non-physical factors that may limit steelhead production. The Restoration Plan will also provided recommendation for habitat improvement in the watershed that may provide the impetus to modify local, state, and federal policies that negatively impact steelhead populations including land-use decisions and water supply issues in the Morro Bay watershed. Through recommendations made in the Restoration Plan, local resource protection agencies or non-profit organizations will be able to pursue appropriate grant funding to implement habitat improvement projects in the watershed.

The first step in the development of this plan was to conduct a baseline habitat and population survey for all accessible, potentially anadromous reaches of the Chorro and Los Osos drainages. Habitat surveys were conducted on Chorro, Dairy, and Pennington Creeks in the Summer of 2001 by the Coastal San Luis Resource Conservation District (CSLRCD) and the California Conservation Corps (CCC). Steelhead distribution and abundance estimates were conducted in October of 2001 by Thomas R. Payne and Associates (TRPA). These data, along with historic information regarding sedimentation, water quality, and streamflow, were summarized in a report produced in March of 2002 by CSLRCD. The Recover Planning Project Report, developed through a cooperative effort between Swanson Hydrology & Geomorphology and CSLRCD synthesizes existing physical and biological data with knowledge of the problems, land use activities, and constraints of future restoration, into a comprehensive steelhead enhancement plan for the recovery of steelhead trout in the Morro Bay watershed.

SECTION 1.1 - BACKGROUND

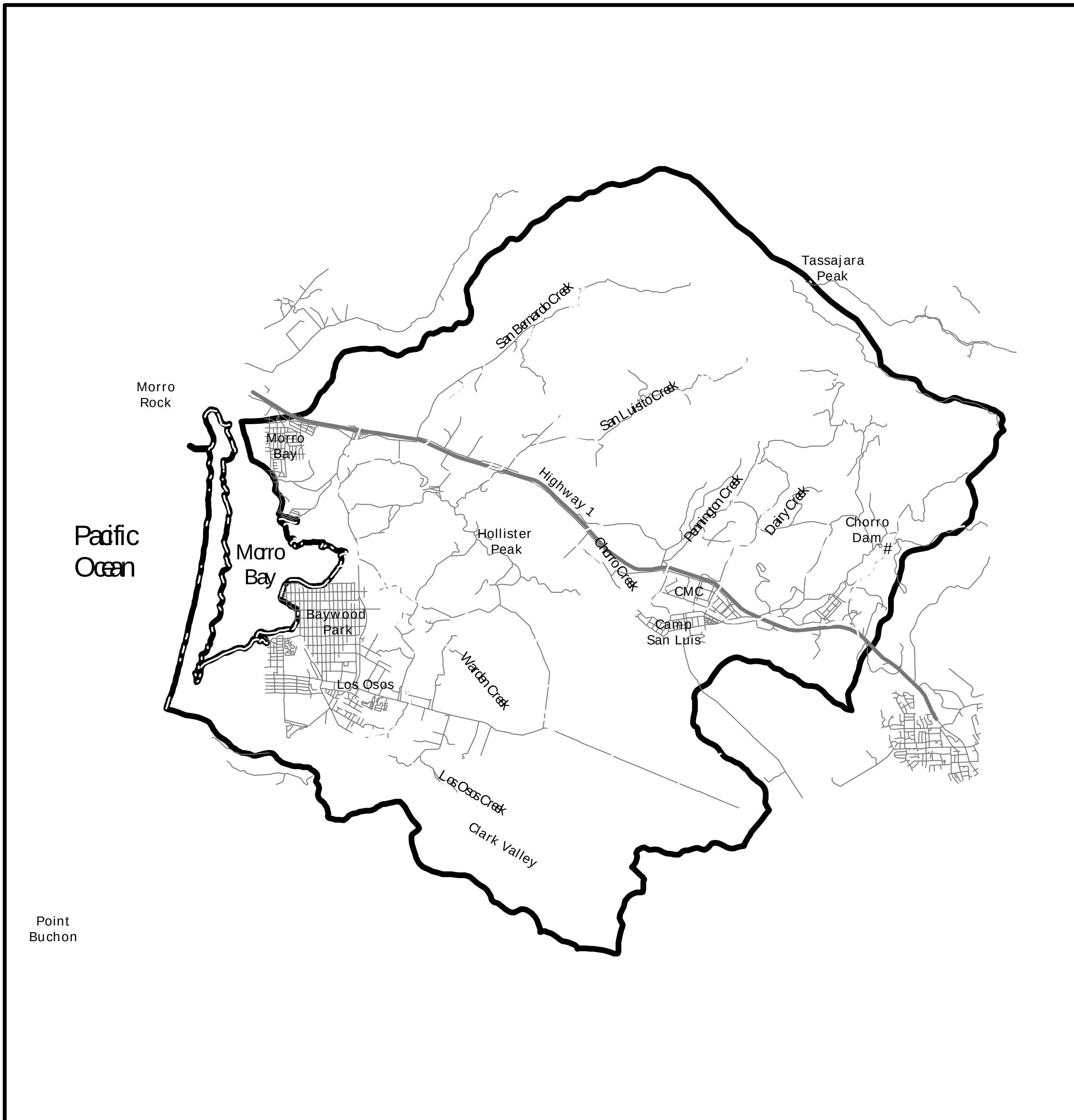
Steelhead trout (*Oncorhynchus mykiss*), according to anecdotal observations and creel census information collected by the California Department of Fish and Game, were once abundant in the streams that drain into the Morro Bay estuary. Their declining numbers in the Morro Bay watershed have mirrored similar reductions in numbers throughout Central Coast streams stretching from the Russian River north of San Francisco, south to Santa Barbara and Ventura Counties. In 1997, due to the declining numbers of steelhead on the Central Coast of California, NMFS designated steelhead trout as a federally threatened species. The populations in Chorro and Los Osos Creeks fall within the South/Central Coast evolutionary significant unit (ESU). This designation protects Morro Bay steelhead from unlawful "take" and puts a priority on their recovery.

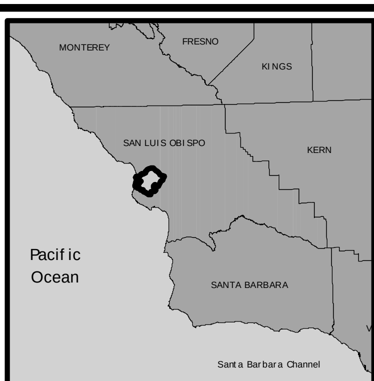
The Morro Bay watershed includes two primary streams, draining approximately 76 square miles of land in San Luis Obsipo County (Figure 1.1). The larger of the two streams, Chorro Creek, drains approximately 65% of the watershed and includes 4 principal tributaries; Dairy, Pennington, San Luisito, and San Bernardo Creeks. The remaining 35% of the watershed drains into Los Osos Creek with most of the fish habitat occurring in Clark Valley.

The watershed consists of a mix of igneous, metamorphic, and sedimentary rock that is part of the Franciscan mélange, a rock unit composed of a mix of rock types brought together by warping, pressure, and tectonism occurring at the plate boundary. Also prominent in the watershed are the "Morros", a line of peaks composed of hard, igneous rocks, formed 25 million years ago as volcanic plugs intruded into softer overlying rocks. It is this line of peaks that separates the Chorro drainage from the Los Osos drainage. The highest elevation in the watershed is 2,763 feet on Tassajara Peak in the Santa Lucia Mountains.

The landscape consists of flat alluvial valleys confined by steep, highly eroding mountains. Typically, shallow soils occur on the hillslopes in the mountainous areas of the watershed with very little capacity to hold water. Conversely, the flat alluvial valleys have deep, well-developed soils that hold significant quantities of groundwater. Land uses in the watershed are closely linked to these landscape characteristics. The flat alluvial valleys adjacent to the streams channels have been historically dominated by agricultural uses. Recently, and in the future, these areas may become the primary land used for expansion of the suburban communities. The Chorro Creek corridor between Morro Bay and San Luis Obispo has seen an increase in development as it transitions from an areas dominated by agricultural land uses to more intensive land uses with increased impervious surfaces. In the wider tributary valleys and mountainous areas of the watershed, the dominant land use has been ranching, especially in the rolling grasslands of the San Bernardo, San Luisito, Pennington, and Dairy Creek tributaries.

The Morro Bay watershed lies within a climatic regime characterized as Mediterranean due to it's cool, wet winters, and warm, dry summer. The close proximity of the watershed to the coast results in cooler summer conditions as a general pattern of onshore flow results in a coastal marine layer. Winter low temperatures are moderated by ocean temperatures making frost and higher elevation snowfall a rarity. Over 90% of the seasonal rainfall in the watershed occurs between the months of November and April, producing a distinct wet and dry season. This rainfall pattern, combined with thin soils in the upper watershed, produces a flashy hydrologic system where winter peak flows can be five orders of magnitude greater than summer baseflow (Tetra Tech, 1998a; CCRWQCB, 2002). During low rainfall years, some reaches of stream that normally flow year-round can dry up or strand juvenile fish in shallow, isolated pools.





Regional Location Map

FIGURE 1.1

Morro Bay Watershed
Steelhead Restoration Plan

Location Map

LEGEND

Streams
Highway 1
Arterial Roads
Watershed Boundary

0.5 0 0.5 1 1.5 2 Miles

N

The flashy hydrologic regime, highly erodible soils, steep slopes, and frequent fire results in the generation of high sediment loads through Chorro and Los Osos Creeks and into Morro Bay. Land use impacts over the past century have accelerated this process, leading to the protection of Morro Bay in the National Estuary Program. Studies completed in 1989 (Soil Conservation Service) and 1998 (Tetra Tech) attempted to quantify the flux of sediment moving into Morro Bay and determine the source components. Though each study arrived at different results depending on the methods used, both studies suggest the majority of delivered sediment is originating from sheet and rill erosion, roadcuts, streambanks, and gullies. Much of the total sediment load was determined to originate in the Chorro Creek watershed (86%) versus the Los Osos Creek watershed (14%). More specifically, 68% of the total estimated sediment load originates in the San Bernardo, San Luisito, and upper Chorro watersheds (above Highway 1) even though they only make up 58% of the total watershed area (Tetra Tech, 1998).

Evidence of heavy sedimentation in Chorro and Los Osos Creeks and the observed decline in steelhead numbers led to the listing of Morro Bay and its tributaries as an impaired waterway for sediment under the Federal Clean Water Act. This designation requires that the Regional Water Quality Control Board develop an approved Total Maximum Daily Load (TMDL) for the watershed (CCRWQCB, 2002). Background sediment loading was estimated along with the present sediment loading to calculate a controllable load. In addition, instream bed condition targets were developed with recommendations to reach the recommended targets as criteria to remove the designation of "impaired waterway". Many of the targets are driven by research defining the range of physical habitat conditions that constitute quality spawning and rearing habitat for salmonids.

SECTION 1.2 - LIFE CYCLES AND HABITAT REQUIREMENTS OF STEELHEAD

Though a wealth of information about steelhead trout (*Oncorhynchus mykiss*) resides in many textbooks and was eloquently described by Shapovalov and Taft in 1954, a brief description and definition of terms used in the remainder of this report is included. Steelhead trout (*Oncorhynchus mykiss*) are genetically indistinct from rainbow trout and differ only in their behavior. Steelhead exhibit a life-cycle strategy similar to other salmonids, known as anadromy, where they spend their adult life in the ocean and swim to their natal stream to reproduce (Figure 1.2). The hatched young, known as fry, spend up to 2 years in these freshwater streams, growing large enough to survive ocean conditions. Once large enough, they make their way to the ocean and undergo physiological changes, a process known as smolting, which allows them to adapt to salty ocean conditions.

Steelhead differ from other salmonids in their unique ability to spawn and return to the ocean with the intention of returning the following year to spawn again, unlike other salmonids which die after spawning. This unique life-cycle pattern make steelhead more resilient to diverse ecological conditions such as a drought or flood because they can return the following year if conditions are not adequate to reach their spawning grounds. Due to these adaptations, steelhead were historically known to occur as far south as Baja California in Mexico and presently range as far south as Malibu Creek in Los Angeles County. Unfortunately, water extractions, dams, and prolonged drought have all but extirpated steelhead from their southern range.

Steelhead trout enter streams and rivers to prepare for migration to spawning grounds as soon as streamflow is adequate and summer sand bars at the mouths of coastal lagoons have breached. This typically occurs in November or December, depending upon the frequency and magnitude of late fall storms. Migration to spawning grounds typically begins in December and can last well into May if late spring storms provide adequate flow to negotiate potential passage barriers.

Spawning occurs within gravel deposits (in the range of 5 to 90 mm) situated at the end or tail of pools and head of riffles. When females dig a nest or redd in the gravel, significant clearing of fine sediment in the gravel deposit occurs (Cordone and Kelley, 1961). Excessive fine sediment (sand and silt) in spawning beds can be detrimental and has been shown to diminish the reproductive success of salmonids by reducing the permeability of gravels, intragravel water flow, and availability of dissolved oxygen for developing embryos (Terhune, 1958; McNeil and Ahnell, 1964; Vaux, 1962; Cooper, 1965; Daykin, 1965). Several researchers have also found an inverse relationship between fine sediment and fry survival (Bjornn, 1968; Phillips et al, 1975). Fine sediment deposited on the streambed also negatively impacts aquatic macroinvertebrate survival and production, a main food source for salmonids (Williams and Mundie, 1978).

The incubation period for steelhead eggs may take up to three months and during that time there must be adequate water circulation to oxygenate the eggs and carry away metabolic wastes. Once hatched, the fish remain in the gravel as sac fry or alevins and have very limited mobility within the gravel deposits. After emerging from the gravel the juvenile fish become very active in swimming to avoid being swept downstream, to seek refuge from predators, and to find food for growth.

The quality of streambed habitat for these life cycle stages can become seriously disrupted by an influx of fine sediments. Coarse substrate and redds can be buried by waves of fine sediments that move along the bed, even during summer low flow periods. The degree to which substrate is buried by fine sediment is known as embeddedness. Fine sediment can clog redds, reduce water circulation and kill or force early emergence of sac fry, thereby decreasing the chances of survival. Fine sediment can also significantly reduce rearing habitat and places to hide, known as escape cover, by burying cobble and boulder areas on the streambed.

Young steelhead spend 1 to 2 years in freshwater streams before heading to the ocean as smolts. The amount of time spent in freshwater depends primarily on food availability and metabolic rates. Each of these factors is highly dependent upon water temperature. As water temperature increases, fish become more active and require more food to support higher metabolic rates. Higher water temperatures allow for more primary and secondary productivity that make more food available to fish. The result is a delicate balance between food availability, water temperature, growth rates, and metabolic rates.

Streamflow also plays an important role in the balance between food availability and growth for steelhead. The quantity of streamflow on a given stream not only dictates the amount of habitat available to fish and aquatic macroinvertebrates (juvenile steelheads preferred food) but also acts as a “conveyor belt” for delivery of food to feeding steelhead. The more streamflow that is available in spring and summer, the more food that is available to be delivered to the fish. As summer flows recede and less habitat becomes available to fish and aquatic macroinvertebrates, the conveyor belt of food slows down. Water temperatures also rise as flows recede in the summer months meaning higher metabolic rates for fish, increasing their food requirements.

The result of interactions between streamflow, habitat availability, and the conveyor belt of food is higher growth rates for fish in the spring months and maintenance or reductions in fish size in the summer and fall months. Differences also occur between colder, smaller tributaries and the warmer, larger mainstem. Steelhead juveniles reared under warmer water conditions (e.g. – mainstem of Chorro Creek) can grow at a fast enough pace to allow them to reach smolt-size (typically > 75 mm Standard Length) within 1 year, whereas juveniles reared under cooler conditions require two years to reach smolt-size due to their slower growth rates. The size a fish reaches when it smolts plays an important role in survival when they reach the ocean. Larger fish tend to have higher survival rates in the ocean because they are often stronger, can swim faster, and have fewer predators that may want to feed on them.

In addition to requiring adequate food for growth, juvenile steelhead have specific habitat requirements, essential to their survival. These include fast-water feeding areas to take advantage of food moving along the "conveyor belt" and locations to hide from predators and high winter flows, referred to as escape cover. Escape cover can include deep pools, undercut banks, side channels, large unembedded cobbles and boulders, rootwads, large woody material, and overhanging vegetation. Streams that lack adequate escape cover will often have low fish densities, regardless of the amount of food available.

The relationship between water temperature and metabolic rate (measured as oxygen consumption) is basic to fish physiology and important in understanding fish distribution and ecology. Fish being ectotherms (cold-blooded), their body temperatures increase along with metabolic rate as water temperature increases. At higher temperatures, steelhead oxygen requirements and food demands increase, and steelhead are forced into fastwater habitat or other sources of abundant food (Fry, 1947; Beamish, 1964; Beamish, 1970). The positive relationship between water temperature and metabolic rate in fishes leads to higher oxygen requirements as water temperature increases (Nikolsky, 1963).

There are many central coast examples of steelhead surviving and growing well at water temperatures above 21ºC. Many of these come from coastal lagoons and lower reaches of unshaded drainages, but only where food is abundant. When food is abundant, growth is actually better at warmer temperatures because digestive rate is increased, allowing fish to consume more food and grow more quickly.

SECTION 1.3 - RESTORATION PLAN GOALS

The primary goal of the Restoration Plan is to develop a long-term strategy to improve conditions for steelhead in the Morro Bay watershed through habitat enhancing measures. The development of a comprehensive restoration plan for steelhead requires several steps that will ultimately lead up to the recommended management or enhancement measures that will guide restoration. The steps used to develop a Restoration Plan for steelhead in the Morro Bay Watershed include the following:

- Review existing habitat and population data,
- Review information regarding physical watershed conditions (ie-water temperature, erosion, etc),
- Develop an understanding of the existing land use infrastructure, water supply needs, etc.,
- Assess the primary limiting factors to steelhead recovery and restoration at the reach scale,
- Formulate opportunities and constraints to steelhead restoration in the watershed,

- Develop recommendations that are feasible and cost effective solutions to enhance steelhead populations, and
- Develop a monitoring plan to evaluate the success of the recommended measures and allow for adjustments based on an adaptive management approach (Not included in this plan).

A majority of the enhancement measures will seek to improve physical habitat because the amount and quality of physical habitat controls the number of juvenile steelhead and adult spawners that can be supported in the watershed. Physical habitat factors that may require enhancement include spawning gravel quality, pool depth and quality, substrate conditions, escape cover, water temperature, and streamflow. Beyond measures to improve physical habitat, this report will also analyze and recommend enhancement measures to reduce the impact of exotic fish populations on steelhead.

The recommendations provided in this report are based on an analysis of existing data and historic reports. Background data and information came from the following reports:

- Huber, A. 2001a. Stream Inventory Report for Chorro Creek. Morro Bay Watershed Steelhead Restoration Planning Process. Coastal San Luis Resource Conservation District
- Huber, A. 2001b. Stream Inventory Report for Pennington Creek. Morro Bay Watershed Steelhead Restoration Planning Process. Coastal San Luis Resource Conservation District
- Huber, A. 2001c. Stream Inventory Report for Dairy Creek. Morro Bay Watershed Steelhead Restoration Planning Process. Coastal San Luis Resource Conservation District
- Otte, F. and McEwen, M. 2001. Existing Data Summary - Morro Bay Watershed. Morro Bay Watershed Steelhead Restoration Planning Process. Coastal San Luis Resource Conservation District
- Payne, T. 2001. The Distribution and Abundance of Steelhead in Tributaries to Morro Bay, California. Thomas R. Payne and Associates.
- CCRWQCB. 2002. DRAFT - Morro Bay Total Maximum Daily Load for Sediment (including Chorro Creek, Los Osos Creek and the Morro Bay Estuary).

The habitat and fish population data is derived solely from the work conducted in the summer of 2001by the CSLRCD and TRPA since it is the most comprehensive and recent dataset available for the Morro Bay watershed. Though the 2001 data is the most comprehensive to date, it is important to note some deficiencies when considering the information in terms a limiting factors assessment, including the following:

1) The habitat data does not include San Bernardo or San Luisito Creeks, both tributaries to Chorro Creek. These two creeks were not included in the habitat assessment due to access issues through private land.
2) Detailed habitat data was not collected on Los Osos Creek due to time and budgetary constraints. Instead, general habitat data was collected on Los Osos Creek to support the population assessment.
3) Population sampling was only conducted on pools and does not account for steelhead populations that may be residing in run and riffle habitat. Only pools were sampled due to the shallow flow conditions present during the time of sampling and the snorkeling method used. Standard electrofishing techniques were not used due to budget and permit concerns. Since only pools were sampled, the total fish population could not be estimated. Density estimates may underestimate the young-of-year fish which often exclusively use riffle and run habitat due to competition for pools from yearling fish. The overall population of

steelhead juveniles in the mainstem of Chorro Creek may be grossly underestimated since any steelhead that are present may be utilizing run and riffle habitat to avoid predation from the high population of Sacramento pikeminnow (Brown and Brasher, 1995; Brown and Moyle, 1991; Moyle and Light, 1996).

4) Population estimates were not conducted in San Bernardo and San Luisito Creeks due to lack of access to private lands. Sampling in Dairy and Pennington Creek was limited due to time and budgetary constraints.

CHAPTER 2 - LIMITING FACTORS ASSESSMENT

SECTION 2.1- INTRODUCTION

For a steelhead to survive to adulthood and then successfully reproduce, a variety of habitat requirements must be satisfied. Interruptions to any phase of a steelheads life cycle can devastate the entire population. When a salmonid fry emerges from an egg, the long process of rearing, migration to the ocean, growing large and returning to spawn has begun. If poor quality habitat, high predation, starvation, or barriers to migration exist, the steelhead life cycle will be cut short. Each of these risks to the steelhead life cycle can be a limiting factor for the entire population (Figure 1.2). This chapter summarizes the key limiting factors to steelhead production in the Morro Bay watershed based on available data.

Following an initial review of available data, the primary factors identified as limiting steelhead production and survival are sediment or substrate conditions, water temperature, barriers to migration, streamflow, and predation from exotic fish. Because physical and biological conditions vary considerable throughout the watershed, each of these potentially limiting factors may vary from place to place in terms of their impact on steelhead populations. To account for differences in controlling variables across the watershed, the analysis was completed based on "reaches" of stream (Figure 2.1). Chorro Creek was divided into a lower, middle, and upper reach with the lower reach ending at the San Bernardo Creek confluence and the upper reach beginning at the dry section near the Highway 1 crossing. Los Osos Creek was also divided into an upper and lower section with the split occurring at the 180-degree bend separating the alluvial flats from Clark Valley. All other tributaries were analyzed as single reaches.

The remainder of this chapter discusses each of the identified limiting factors in more detail including a discussion of its importance, what the impacts are on steelhead populations, and where in the watershed the impacts are most acute. Each specific limiting factor can overlap with each other, especially factors such as sediment which have an effect on streamflow and ultimately temperature. The limiting factors are discussed in a non-specific order and therefore do not reflect their level of importance to steelhead survival. A final section summarizing the limiting factors assessment is also included to provide a big picture of the dominant impacts to steelhead reproduction and survival in the Morro Bay watershed. Chapter 3 discusses specific management recommendations or enhancement actions that, if implemented, will improve conditions for steelhead in the Morro Bay watershed by addressing the identified factors limiting their numbers.

SECTION 2.2 - SEDIMENT CONDITIONS (AS THEY RELATE TO HABITAT QUALITY)

Excessive input of sediment into the waterways that make up the Morro Bay watershed has been identified in numerous reports to impair aquatic habitat quality (Tetra Tech, 1998; CCRWQCB, 2002; MBNEP, 2000; SCS, 1989; RCD, 1989). Though erosion of hillslopes and delivery of sediment to stream channels for eventual transport to Morro Bay and the Pacific Ocean is a natural process, anthropogenic land use impacts have accelerated the rate of delivery.

In the Morro Bay watershed, the process of accelerated sediment delivery to stream channels is caused by a series of positive feedback mechanisms driven by the intensity of land use and the inability of stream channels to adjust to rapidly changing conditions in the watershed. The process is likely the result of increased peak storm runoff as altered surfaces become less pervious and contribute a greater percentage of storm rainfall to sheetflow and surface runoff as opposed to slower runoff processes involving percolation into the soil and groundwater movement. Accelerated delivery of water from the hillslope to the channel ultimately steepens and magnifies the storm peak hydrograph with significant impacts to the morphology of the channel (Thom et. al, 2001; Booth and Henshaw, 2001). The result of such a scenario is higher hillslope erosion due to rilling and gullying and increased bank erosion and channel downcutting as the channel attempts to adjust to higher peak flows by widening and deepening the channel.

The problem is accelerated when the amount of impervious surface in a watershed is continually increasing. The land use pattern in the Morro Bay watershed has been from a native grassland/chaparral ecosystem to an agricultural rangeland dominated landscape and then recently to an urban/suburban setting. Each of these land use conditions results in an increase in impervious surfaces and subsequently more runoff. The result is a channel pattern and morphological condition of constant adjustment to a new equilibrium condition. Without sufficient time to reach a new state of equilibrium between channel width, depth, and meander pattern, the constant state of adjustment has resulted in complete unraveling of many stream banks throughout the Morro Bay watershed. The predominance of streambank erosion is evidenced in the Stream Inventory Reports for Chorro, Pennington, and Dairy Creeks (Huber, 2001abc).

Not all erosion is necessarily detrimental to steelhead populations. Steelhead require significant quantities of coarse gravel for spawning and cobble and boulder substrate to provide escape cover. The grain sizes that result in impairment of habitat quality are from sediments that are sand size and smaller that clog spawning gravels and bury cobble and boulder substrate, reducing the total amount of escape cover. How sediment is delivered to the channel also determines its potential impact on habitat quality. Episodic events, such as landslides, often occur during peak runoff events when there is adequate flow and velocity in the channel to move fine grain sediment through the system and minimize its impact on the channel. During high flow events, finer sediment will either be flushed through the system or be deposited in the floodplain or channel bars during recession flows. Conversely, chronic inputs of sediment from eroding banks, gullies, or road ditches will deliver fine sediment during most flow events. During low flow events pool velocities are often too low to transport sediment resulting in deposition and filling of pools with fine-grained impairing sediment.

In the streams of the Morro Bay watershed, sediment appears to limit rearing habitat quality more than it does spawning habitat quality. Though it is difficult to determine whether the available habitat is saturated by young-of-the-year (YOY) fish, visual observations of pool tail outs throughout the watershed and embeddedness data collected by the CSLRCD suggest that enough spawning habitat is available given the low number of adult steelhead returns. The habitat survey results for Chorro, Pennington, and Dairy Creeks suggest that pool tails are dominated by gravel substrate (Huber, 2001abc). High winter flows and the amount of gravel substrate present in the watershed, along with the activities of the female spawners to clean gravel substrate prior to laying her eggs (Bjornn, 1968) put spawning habitat quality low on the list of potential limiting factors (see Table 2.6).

At the reach scale, pool tail embeddedness varies considerably. Table 2.1 summarizes the results of embeddedness from the 2001 habitat surveys (Huber, 2001abc). Embeddedness is presented as a percent value within each class with classes ranging from 1 to 4, with each class representing a 25 percent range (e.g. 1 = 0 to 25%, 4 = 75 to 100%). Embeddedness class 5 is reserved for habitat units that lack suitable spawning substrate. To establish a relative ranking between reaches, each class was multiplied by a factor and then summed. The multiplying factor was 2, 1, 0, -1, and –2 for embeddedness class 1, 2, 3, 4, and 5, respectively. The final score has a range between 200 and –200 with 200 representing extremely low embeddedness and –200 representing extremely high embeddedness. Negative scores suggest the reach has the potential to be limited by the quality of spawning habitat. The locations with the best spawning habitat appears to be the middle reaches of Chorro Creek, lower Pennington Creek and most of Dairy Creek. Percent embeddedness was not estimated in Los Osos and other major tributaries to Chorro Creek. The results suggest adequate spawning habitat is likely to be available given the current number of adult spawners.

Table 2.1: Embeddedness Values for Morro Bay streams, by reach. Pool-tail embeddedness is a measure of spawning habitat quality.

Restoration Plan Reach	Habitat Typing Reach Number	Percent Pool-tail Embeddedness Value by Class					Index of Spawning Habitat Quality
		1	2	3	4	5	
Lower Chorro	1	6	13	14	63	5	-48
Middle Chorro	2	25	17	8	42	8	9
Middle Chorro	3	20	21	11	32	15	-1
Middle Chorro	4	25	30	5	5	35	5
Middle Chorro	5	21	12	21	39	6	3
Upper Chorro	6	0	20	30	50	0	-30
Upper Chorro	7	0	22	56	11	11	-11
Upper Chorro	8	0	0	0	29	71	-171
Pennington	1	25	31	31	0	13	55
Pennington	2	20	38	25	12	6	54
Pennington	3	6	31	25	19	19	-14
Pennington	4	0	33	28	0	39	-45
Dairy	1	5	27	64	5	0	32
Dairy	2	14	24	45	6	12	22
Dairy	3	19	31	13	0	38	-7
Dairy	4	11	42	29	9	9	37
Dairy	5	6	38	6	13	38	-39
Dairy	6	26	22	19	7	26	15

Though excessive sediment loads may not have a significant impact on spawning habitat, the data from the 2001 habitat and population surveys (Huber, 2001abc; TRPA, 2001) suggest that it may have a significant impact on rearing habitat in the Morro Bay watershed. Excessive sediment loads, especially the fine sediment component, can reduce the quality of rearing habitat by reducing habitat depth and volume and reduce the complexity of instream cover for young steelhead to escape predators. Measured indicators of these parameters include average pool depth, the percent of the total habitat represented by pools, the percentage of pools that are deep (> 3 feet), and the level of complexity of instream cover.

Table 2.2 summarizes the critical rearing habitat parameters that relate to channel sedimentation. The shelter rating is determined by multiplying the percent of each habitat unit that can be considered shelter for fish by a rating from 1 to 3 describing the complexity of the shelter. The final rating is a value from 1 to 300 with 300 being a complex, highly sheltering habitat unit.

Shelter rating was not estimated for Los Osos Creek since it was not part of the habitat typing work conducted by the CSLRCD.

The results presented in Table 2.2 suggest an adequate number of pools occur throughout the watershed, though the pools appear to shallow and devoid of shelter, indicating an overall lack of high quality rearing habitat. According to the data, Chorro Creek contains the best rearing habitat of all the sampled streams with a good percentage of pools greater than three feet deep and high shelter ratings compared to other streams. Pennington, Dairy, and Los Osos Creek lack deep, complex pools favored by yearling steelhead. The lack of complexity is likely due to a combination of sedimentation, historic channel modifications such as straightening or encroachment from roads or agricultural lands, and lack of complex structural elements such as large woody debris. The dominant shelter type throughout the watershed consists of boulders and cobbles. Though these roughness elements provide cover for fish, they lack the complexity of large woody debris. Historically, boulders, bedrock outcrops, and undercut banks might have made up the majority of the shelter elements in the Morro Bay watershed due to the lack of large coniferous trees such as redwood and Douglas-fir that dominate streams in the Pacific Northwest (Keller and Talley, 1979; Keller and Swanson, 1979; Keller et. al., 1981). Oak, alder, sycamore, and willow dominate the canopy in Morro Bay streams but break down quickly or get washed away, providing little in the way of channel stability, roughness, or shelter for fish.

Table 2.2: Rearing habitat parameters affected by excessive sedimentation, by reach.

Restoration Plan Reach	Habitat Typing Reach Number	Mean Pool Depth	Pools by Stream Length (%)	Pools >= 3 Feet Deep (%)	Shelter Rating
Lower Chorro	1	1.2	26	10	25
Middle Chorro	2	1.4	40	40	105
Middle Chorro	3	1.4	45	14	26
Middle Chorro	4	1.8	59	32	83
Middle Chorro	5	1.3	22	19	17
Upper Chorro	6	1.4	31	40	9
Upper Chorro	7	1.6	43	44	28
Upper Chorro	8	1.3	38	29	25
Pennington	1	1.4	42	13	25
Pennington	2	1.1	29	7	28
Pennington	3	1.0	9	0	22
Pennington	4	1.0	16	11	27
Dairy	1	0.9	25	5	15
Dairy	2	1.2	36	6	28
Dairy	3	1.3	33	29	10
Dairy	4	1.2	19	2	23
Dairy	5	0.8	10	7	13
Dairy	6	0.8	14	0	10
Lower Los Osos	Lower	0.85	28	0	NA
Upper Los Osos	Middle	0.84	32	0	NA
Upper Los Osos	Upper	0.86	29	0	NA

SECTION 2.3 – WATER TEMPERATURE AND PREDATION FROM EXOTIC FISH SPECIES

When field books and fishing guides describe a stream, they often classify it into either a cold water or warm water fishery. This designation is used because the temperature of the water as either cold or warm immediately connotes a certain assemblage of fish species or fish types that you would expect to find there. In coastal California, the separation between a cold water and warm water fishery is often the separation between a flowing, natural stream and an artificial reservoir. Because natural streams are often spring-fed and have a dense riparian canopy, the water remains cold enough year-round to support an assemblage of fish species that are adapted to cool conditions. In a reservoir, lack of any significant shading raises water temperatures above the threshold that favors species more adapted to warmer water temperatures and potentially lower dissolved oxygen concentrations.

Steelhead trout are considered to be a fish that belongs to the cold water fish species assemblage. As the water temperature increases, their metabolic rate increases, forcing them to find and eat more food in order to maintain and/or increase their body weight for eventual survival in the ocean (Smith and Li, 1983; Beamish, 1964; Beamish, 1970). If adequate food is available, steelhead juveniles may actually grow faster with the potential for smolting after a single year in freshwater. This creates a delicate balance between temperature and food supply that is not easily quantified. Additionally, if water temperatures are too high, oxygen dissolved in the water becomes inaccessible to fish, resulting in direct mortality (Alderdice, 1958).

Studies conducted on steelhead and rainbow trout in the Pacific Northwest suggest that the maximum temperature threshold is approximately 20°C (68°F) (Shapovalov and Taft, 1954). This number is often used as a water quality target to maintain a cold water fishery for steelhead and other salmonids. Though steelhead can survive warmer temperatures higher than this recommended threshold, given adequate food supplies and high dissolved oxygen levels, factors such as a limited food supply and competition and/or predation from species adapted to warmer water temperatures make this a reasonable water quality/temperature target.

In the Morro Bay watershed, temperatures above the target threshold often occur in the mainstem of Chorro Creek where average maximum temperatures can exceed 70°F on a regular basis in the summer and fall months (Table 2.3; Otte and McEwen, 2001). High summer and fall water temperatures favor the introduced Sacramento pikeminnow (formerly Sacramento squawfish). Pikeminnow were likely introduced as bait fish into Chorro Reservoir and eventual made their way into the mainstem of Chorro Creek through peak flow reservoir spills.

Table 2.3: Average summer high water temperatures (June – August) at monitoring locations in the Morro Bay watershed. Because these represent average high temperatures, instantaneous maximums will be higher. (MBNEP, 1995-1999)

Location	Average Summer High Water Temperatures (°F)				
	1995	1996	1997	1998	1999
Chorro Creek @ Canet Road	71	76	70	75	64
Dairy @ Highway 1	67	69	69	68	64
Pennington Creek @ Highway 1	76	70	75	64	70
Los Osos Creek @ Los Osos Valley Road	62	77	65	72	70

The release and eventual spread of pikeminnow into Chorro Creek must have occurred after 1976 when a DFG study reported that Chorro Creek, between Canet Road and Chorro Reservoir sustained approximately 60 percent of the juvenile steelhead population in the Morro Bay watershed (Chappell et. al., 1976). Subsequent to that report, pikeminnow have become the dominant fish species throughout the mainstem of Chorro Creek downstream of the reservoir. In fact, no young-of-the-year and very few yearling steelhead were observed in Chorro Creek in the TRPA population survey (TRPA, 2001) though it is likely that some steelhead may occur in the run and riffle habitat.

Pikeminnow (*Ptychocheilus grandis*) are a large cyprinid species native to the Sacramento River, Russian River, and some of the larger tributary streams that drain into Monterey Bay. The pikeminnow is a large predatory cyprinid. They can grow to a size of 500 mm (20 inches) and typically begin to feed on other fish when they are greater than 100 mm (4 inches). The predatory habits of the pikeminnow are well documented due to their introduction in the Eel River in the late 1970's, early 1980's. Researchers on the Eel River have documented major changes in the number and distribution of salmonid species, including steelhead, in response to the introduction of pikeminnow and subsequent expansion of their range. Salmonids in the Eel River, in response to the presence of pikeminnow, were either confined to riffle or run habitat or the margins of pool habitat, or were only found in cooler tributaries where pikeminnow were absent (Brown and Brasher, 1994; Brown and Moyle, 1991; Moyle and Light, 1996).

Other non-native fish species may be present in the mainstem of Chorro Creek including bluegill and bass, both of which are predators on juvenile salmonids. Higher water temperatures in Chorro Creek due to loss of mature riparian canopies has converted the mainstem of Chorro Creek, especially the lower and middle reaches, to a habitat condition that favors warm water species, such as the pikeminnow, over cold water species, such as steelhead.

Another source of increased water temperatures in Chorro Creek may be the California Mens Colony's Wastewater Treatment outfall. The treatment plant discharge point, located just downstream of Cuesta College on Chorro Creek, releases an average of 1.1 cubic feet of reclaimed water per second in the summer months (June through August) (CMC, unpublished data). Through the process of treating the sewage, the water is often heated and is released to Chorro Creek at a higher temperature than the receiving waters. In most cases the temperature increase in Chorro Creek due to the effluent release is approximately 2°C (3.6°F) warmer than upstream of the outfall (CMC, unpublished data). Though the temperature increase may appear small, during the summer months it can be enough to raise the water temperature above the 20°C threshold for steelhead trout.

Based on the population data collected by TRPA (TRPA, 2001) and observations made during the habitat typing work (Huber, 2001abc), pikeminnow have not invaded Dairy or Pennington Creeks and have no freshwater connection to Los Osos Creek. Pikeminnow appear to be excluded from Dairy and Pennington Creeks by culverts located at the Highway 1 crossings for each creek. These culverts appear to be either jumping or velocity barriers for pikeminnow under all flow conditions but allow steelhead passage under an unknown range of flow conditions. This issue is discussed further in the barriers section of this report (Section 2.4).

High summer water temperatures also appear to be a problem throughout the streams of the Morro Bay watershed (Table 2.3; Otte and McEwen, 2001). Dairy is the only creek that consistently stays under 70°F in the summer months. Gaps in the riparian corridor, low summer baseflow conditions, and summer heat waves combine to raise the stream temperatures above what is considered optimal for steelhead rearing. In many cases, steelhead juveniles will become inactive during peak daylight hours to avoid high water temperatures. They will often seek refuge locations where cooler pockets of water occur such as locations of springs or deeper pools that stratify in temperature during the day with cool water at the bottom (Matthews and Berg, 1997). This underscores the need for deeper pools that can provide refugia for juvenile steelhead during periods of peak water temperature.

SECTION 2.4 – BARRIERS TO MIGRATION

A discussion of barriers is necessary in order to understand the current upstream limits of anadromous fish habitat and to determine the potential habitat that would be available to spawning adult steelhead if the barriers were removed or modified to allow fish passage. Passage impediments can include man-made features such as flashboard dams, diversions, culverts, low-water crossings and reduced streamflow conditions that limit migration past critical riffles. They also include natural features such as bedrock shelves, waterfalls, and high-gradient riffles. Passage impediments can also range from complete barriers that limit upstream migration under all flow conditions (e.g. - a 20-foot high waterfall) as well as partial barriers that may only limit migration under certain flow conditions.

In the existing data summary, prepared by the CSLRCD (Otte and McEwen, 2001), twelve barriers were identified in the principal streams draining into Morro Bay. These barriers were identified based on conversations with DF&G staff and habitat surveys conducted by the CSLRCD and the CCC (Huber, 2001abc). In spring of 2002, as part of the field reconnaissance for development of this plan, we visited as many sites as were accessible to evaluate the condition of each site and provide preliminary recommendations. Each site is expected to be surveyed in more detail and analyzed using a fish passage software program developed by the U.S. Forest Service with cooperation from Humboldt State University. This survey is being funded by the CSLRCD and will be conducted in the fall of 2002.

Table 2.4 and Figure 2.2 summarize the location, condition, and preliminary prioritization of each of the potential barriers identified to date. Very little information is available for San Bernardo and San Luisito Creeks due to access constraints. Therefore, the maximum extent of anadromy has not been identified on these two creeks. A total of fifteen barriers are mapped and described. Priorities for restoration at each of the site are based on the degree to which each site is a barrier, the feasibility of improving passage at the site, and the amount of habitat that would be available if passage was provided past the site.

Modification to the culvert crossings at Highway 1 on San Bernardo, San Luisito, Pennington, and Dairy Creeks need to be carefully considered due to the presence of pikeminnow throughout Chorro Creek. Any plans and specifications developed for these culvert crossings needs to maximize passage for steelhead adults and juveniles while completely preventing passage by pikeminnow. This balance may require that the culvert remain a barrier for some life stages or during certain flow conditions to prevent access to pikeminnow. Introduction of pikeminnow could be devastating to steelhead populations in these tributary streams.

Table 2.4: Description and prioritization of passage barriers. Site numbers were adopted from the Existing Data Summary (Otte and McEwen, 2001). Sites 6 and 10 were dropped because the site did not appear to be a barrier (#6) or information was lacking regarding the location (#10). Sites were included as they were identified and information was provided.

Stream	Site Number	Description	Priority
San Luisito	1	Culvert and grouted rock spillway at Highway 1. The drop is ~ 5' high with a 20' long concrete apron upstream. The site presents a barrier at most flows. Evidence of downcutting downstream, which will increase the barrier height over time. Improvements may include boulder vortex weirs downstream to reduce the jump height and flow concentration across the concrete apron.	High
San Luisito	2	Culvert at Adobe Road just upstream of Highway 1 culvert. The culvert consists of two concrete box culverts with a flat concrete bOttem. A channel has formed in the left box (looking downstream) providing better low flow conditions. This should be enhanced through structural work and a baffle system to reduce high flow velocities. The jump is negotiable for adults but may be difficult for juveniles.	Medium
Dairy	3	Culvert at Highway 1 crossing. A large pool at the base provides ample depth to develop jumping speeds but boulder energy dissipaters at culvert outlet blocks entrance under most flow conditions. The culvert is also very wide resulting in shallow conditions under low to moderate flows. A low flow channel with baffles should be established through the culvert with energy dissipation achieved in a different manner.	High
Dairy	4	Culvert at El Chorro Regional Park. This site consists of a single 5' circular CMP buried slightly below grade. During high flows, the capacity of this culvert may be exceeded resulting in overflow across the road. Large boulders placed at the upstream end of the culvert may produce turbulent conditions under moderate flows and impede access. This site should be analyzed to determine if a larger culvert is required. At a minimum, the upstream boulders should be reconfigured to improve passage.	Medium
Chorro	5	Bedrock falls ~ 9' high. This may be a complete barrier except under extremely high flow conditions when adequate backwatering may bring the downstream pool elevation up high enough to allow a jump. A bedrock channel upstream of the falls would still make passage difficult. This may be the upstream end of anadromy for steelhead on Chorro Creek.	None
Chorro	7	Pipe crossing and concrete sill/grade control at CMC. A notch was created to improve passage. Subsequent downcutting has resulting in a slight passage barrier for juveniles under low flow conditions. Downstream rock weirs could improve passage by backwatering pool to sill elevation.	Low

Stream	Site Number	Description	Priority
San Bernardo	8	Culvert crossing just upstream of Highway 1. This site consists of 3 – 3' CMP's. Due to their small size, the culverts are likely to plug with debris resulting in overtopping of the road. Recommend replacement with a span bridge or partially buried CMP large enough to accommodate high flow events and debris. Careful consideration should be made to the design to account for pikeminnow passage since the Highway 1 culvert does not appear to be a barrier. Surveys should be conducted as part of the retrofit to determine if pikeminnow already occur on San Bernardo Creek upstream of this high flow barrier.	Low
San Bernardo	9	Bridge on San Bernardo Creek. We were unable to assess this site due to access constraints. It is reported to be a bridge structure with a center pillar that can act as a flashboard dam. It may act as an impediment to adult passage due to the structural conditions at the bridge.	Unknown
Dairy	11	Rock dam at El Chorro Regional Park. The structure consists of a 2' high rock dam on top a bedrock shelf. Though modification have been made to the rock dam, the entire structure should be removed to improve passage. The site may still act as a low flow barrier under natural conditions.	Medium
Chorro	12	Chorro Dam and Reservoir. This site is a complete passage impediment to steelhead. Though the capacity of the reservoir as been diminished significantly by sedimentation, there are no future plans to remove the dam. The water stored behind the dam acts as the sole source of water for Camp San Luis Obispo.	Low to None
Pennington	13	Culvert at Highway 1 crossing. This site presents a barrier under low flow conditions due to shallow flows through the culvert. An existing baffle system is dysfunctional due to sedimentation and should be redesigned to match current design criteria. The downstream concrete step weirs are functioning well.	Medium
Chorro	14	Grouted rock dam and culvert. This site was possibly an old low-water crossing consisting of a grouted rock spillway with a single 12" culvert that has completely sedimented in. Removal of the rock dam and culvert would improve passage under low flow conditions.	Low
Los Osos	15	Bedrock falls ~ 8' high. This was judged to be a complete barrier under all flow conditions and represents the upstream end of anadromy for steelhead on Los Osos Creek.	None
Dairy	16	Bedrock falls ~ 40' high. Upstream end of anadromy on Dairy Creek.	None
Pennington	17	Boulder cascade ~ 200' long with a 45-60% slope. Determined to be the upstream end of anadromy on Pennigton Creek.	None

SECTION 2.5 - STREAMFLOW

In a climate where rainfall is seasonal, streamflow is often a scarce resource for human systems where there are demands for municipal, agricultural, and industrial uses as well as fire protection and recreation. All of these human demands for water compete with the need to maintain streamflow for biological systems. Human water demand also peaks during summer and early fall when streams are experiencing their lowest flows of the year. Due to the low streamflow during the summer months in most streams, streamflow is likely to be a limiting factor for fish production even in the absence of human use of this valuable resource. When water extractions are added, streamflow as a limiting factor becomes even more significant.

Streamflow as a limiting factor can, and has been, discussed in the context of other limiting factors such as rearing habitat for juveniles and passage barriers for adults. It is the primary element that defines total available habitat for salmonids with other secondary limiting factors affecting the quality of the habitat and the ability to reach available habitat.

In the Morro Bay watershed, streamflow conditions are likely to be a significant limiting factor for steelhead rearing in all primary streams. Summer baseflows, especially during drought years, can be extremely low with some portions drying up completely. In 1994, at the Canet Road gage on Chorro Creek, the September minimum flow was measured at 0.05 cfs. June through November of the same year had minimum flow values less than 0.3 cfs (Komex, 2000; Otte and McEwen, 2001). Average summer flow conditions on Chorro Creek often range from 1 to 3 cfs, except during dry years. In 1994, on Chorro Creek, the average August flow was 0.25 cfs. In 1995 during the same month, the average flow was 7.85 cfs.

Due to lack of historic streamflow data on Chorro Creek, it is difficult to determine what the unimpaired flow condition would be. Chorro Reservoir and groundwater pumping for agricultural and municipal uses have both had a significant impact on the timing and quantity of baseflow through reductions in surface water and lowering of the water table in the Chorro valley. Channel sedimentation may also have a significant impact on baseflow conditions by causing more water to flow subsurface along with shorter residence times in shallow pools. At Chorro Reservoir, CMC is required to bypass a minimum of 1 cfs from the reservoir when inflow into the lake is greater than 2 cfs. When inflow falls below 2 cfs, CMC is required to bypass half the inflow amount (CMC, personal communication). Table 2.5 summarizes summer releases from Chorro Reservoir from 1995 to 2001. In many cases, the inflow into the reservoir is estimated based on water surface elevation and use records which may be inaccurate and does not account for evaporation off of the lake surface. During dryer years, the releases from Chorro Reservoir may not be adequate to support downstream steelhead populations.

An argument can also be made to suggest that summer baseflows have been augmented in Chorro Creek through importation of state water and consistent summer releases by the wastewater treatment facility on Chorro Creek run by the California Mens Colony. This facility continuously releases an average of 1.1 cfs during the summer months (CMC, unpublished data) with a minimum instantaneous release rate of 0.75 cfs. Due to fluctuations of influent at the plant there is considerable fluctuation in the effluent making this an unpredictable source of flow. The City of Morro Bay has also proposed a scenario where reclaimed wastewater is released into Chorro Creek in the same general vicinity as the CMC outfall site. This project, if implemented, would release between 1 and 1.5 cfs on a continual basis to augment flows in Chorro Creek. The City of Morro Bay currently has the rights to pump water from wells adjacent to Chorro Creek, as long as streamflow remains above 1.4 cfs. These wells are not often used with much of the demand for water expected to come from the State Water Project (Bill Boucher, personal communication).

Table 2.5: Average monthly summer releases (in cfs) from Chorro Reservoir from May to October. The average for May through October is also shown along with the average inflow into the reservoir for the same months.

Month	**'88**	**'89**	**'90**	**'91**	**'92**	**'93**	**'94**	**'95**	**'96**	**'97**	**'98**	**'99**	**'00**	**'01**
May	0.23	0.45	0.22	0.43	0.77	1.73	0.38	1.55	1.55	1.52	1.41	1.34	1.34	1.24
Jun	0.26	0.39	0.27	0.33	0.66	1.73	0.31	1.55	1.28	1.14	1.41	NA	1.34	1.24
Jul	0.09	0.31	0.20	0.29	0.62	1.05	0.27	1.25	0.83	0.66	1.41	1.34	1.34	1.24
Aug	0.18	0.22	0.15	0.26	0.53	0.86	0.24	0.90	0.68	0.53	2.03	1.34	1.34	1.24
Sep	0.29	0.22	0.14	0.25	0.43	0.69	0.28	0.64	0.57	0.92	2.13	1.34	1.34	1.24
Oct	0.31	0.22	0.14	0.25	0.40	0.55	0.25	0.58	0.54	1.27	1.52	1.34	1.57	0.81
Avg.	**0.23**	**0.30**	**0.19**	**0.30**	**0.57**	**1.10**	**0.29**	**1.08**	**0.91**	**1.01**	**1.65**	**1.34**	**1.38**	**1.17**
Inflow Avg.	***0.58***	***0.54***	***0.37***	***0.60***	***1.14***	***2.11***	***0.58***	***3.12***	***1.64***	***1.55***	***3.28***	***2.63***	***1.48***	***1.29***

The tributary streams to Chorro Creek, including San Bernardo, San Luisito, Pennington, and Dairy Creeks, vary considerably in the amount of baseflow. During the spring months, San Luisito appears to have the highest baseflow of the four major tributaries with Dairy having the lowest (Figure 2.3). In the summer months, baseflow in each tributary tends to even out with San Luisito consistently having flows 2 to 3 times higher than the other tributaries (based on 2001 data). It is likely these tributaries have naturally low baseflows although groundwater pumping and lack of in-channel storage could have a significant negative impact on rearing conditions. Augmenting baseflows in these tributaries to improve rearing habitat for steelhead may not be feasible.

Los Osos Creek, particularly in Clark Valley, has some of the higher steelhead juvenile densities in the watershed (TRPA, 2001) even though it has some of the lower baseflow conditions. During the TRPA population sampling in October of 2001, flow in Los Osos Creek was estimated to be 0.1 cfs with numerous intermittent and dry sections. The lower portion of Los Osos Creek is purported to be dry during the summer months in most years and was dry during a reconnaissance survey in March of 2002. The lack of any high peaks and well pumping for ranching and agricultural uses in the Clark Valley combine to produce low baseflow conditions. A lack of deep pools also contributes to the "appearance" of less water and reduces overall habitat area for steelhead juveniles. Similar to the tributaries to Chorro Creek, augmentation of existing baseflows in probably not a feasible solution in Los Osos Creek.

To adequately determine what the optimal flow conditions should be to rear the maximum number of steelhead juveniles through different reaches of streams in the Morro Bay watershed, an IFIM model would need to be developed. This model is essentially a rating curve that defines the relationship between habitat quality and flow through a surveyed section of stream. Unfortunately, developing an IFIM model for even a small section of stream is a very time intensive and costly undertaking. What is clear from the flow data available for Los Osos, Chorro, San Bernardo, San Luisito, Pennington, and Dairy Creeks is that current flow conditions are suboptimal. Any additional streamflow would ultimately improve rearing conditions for juvenile steelhead by increasing the amount of habitat, providing more invertebrate production, and lowering water temperatures.

SECTION 2.6 – SUMMARY OF LIMITING FACTORS

Under pre-European conditions, steelhead trout in the Morro Bay watershed where constantly battling for survival in a system of low summer baseflows, high winter peak flows, and extended periods of drought that would have often decimated entire year classes of juveniles. These marginal conditions have been exacerbated by past land use practices that include intensive grazing, modification to creek channels to make room for agriculture, and road building in the upper watershed that has increased sediment loads to the lower reaches. Over the last several decades, urban populations have expanded, resulting in further degradation of the natural channel system and water balance that supported a highly fluctuating population of steelhead trout trying to survive on the margins of its range.

Historically, the most productive steelhead reach in the Morro Bay watershed was Chorro Creek. It has the highest summer baseflow, contained deep pools, a functional floodplain, and dense willow riparian areas that likely produced a large amount of insects for steelhead to feed on. Today in Chorro Creek, there are still deep pools, baseflow is still adequate to support a large juvenile population, and efforts are underway to restore riparian and floodplain area. Unfortunately, the potential for high juvenile steelhead production is limited by the introduction of the Sacramento pikeminnow, a voracious predator that has spread throughout Chorro Creek and pushed steelhead juveniles to the margins of their primary habitat and into tributary habitat where pikeminnow have been excluded. High water temperatures, near the recommended threshold for steelhead trout, have contributed to the condition found on the mainstem of Chorro Creek by favoring a warm water over a cold water assemblage of fish species. To improve conditions, watershed-wide, for steelhead trout in the Morro Bay watershed, the biggest single improvement would be to eradicate exotic fish in Chorro Creek and Chorro Reservoir, the ultimate source of the pikeminnow, and potentially, other exotic predator fish. Unfortunately, there are few successes in the restoration field when it comes to removing exotic species. Though the pikeminnow, by itself, would not extirpate steelhead trout from Chorro Creek, they can have a significant impact on their total numbers and ability to withstand other stressors present in the watershed.

For the tributaries to Chorro Creek and Los Osos Creek, the primary limiting factor is ultimately summer streamflow. Additional summer streamflow, if available, would dramatically increase the amount of available habitat and lead to higher invertebrate production. Unfortunately, on most of these streams, there is very little opportunity to increase streamflow to a significant level. Beyond streamflow, which would likely be a limiting factor even under historic pre-European conditions, the best way to improve conditions for steelhead would be to remove passage barriers and increase the quality of rearing habitat.

Declining populations in Chorro Creek due to pikeminnow predation would leave a larger percentage of the population in the Chorro tributaries. Improving access conditions to the Chorro Creek tributaries would allow steelhead to access spawning and rearing grounds. A case in point may be Los Osos Creek where only a single, natural passage barrier was identified during the surveys conducted in fall of 2001.This stream, by far, had the largest density of steelhead juveniles, even though the rearing habitat is fairly marginal (TRPA, 2001). A relatively intact riparian canopy and a lack of non-native predatory fish provided for enough habitat to maintain a suboptimal, but stable population of steelhead juveniles.

Following barrier removal on the Chorro Creek tributaries, rearing habitat could be improved through watershed-wide reductions in fine sediment input. Additionally, structural elements, such as boulders, can be strategically placed in the stream channel to improve channel scour conditions and increase pool depths.

Table 2.6 summarizes, by stream reach (see Figure 2.1 for a map delineating stream reaches), the primary factors that limit steelhead production in the Morro Bay watershed. Each reach is ranked, by factor, as highly limiting, moderately limiting, minimally limiting, or not limiting. Each ranking was assigned regardless of the reason that factor is considered limiting. For example, as stated earlier, streamflow is likely to be a limiting factor independent of any water extractions or streamflow reductions caused by human use of the watershed. Locations where enhancement measures can improve the conditions of a particular limiting factor are noted. The degree to which a particular factor is limiting should ultimately be compared to other limiting factors in the same reach though some comparisons can be made from reach to reach.

Table 2.6 – Limiting factors assessment summary for steelhead bearing streams tributary to Morro Bay.

LOCATION	SEDIMENT		BARRIERS	STREAMFLOW	TEMPERATURE	PREDATION
	Spawning	Rearing				
Lower Chorro Creek	•	•		●	⬤	⬤
Middle Chorro Creek	•	●		●	⬤	⬤
Upper Chorro Creek	●	●	⬤	●	●	⬤
San Bernardo Creek	**NA**	**NA**	●	○	●	**NA**
San Luisito Creek	**NA**	**NA**	⬤	◦	●	**NA**
Pennington Creek	•	⬤	●	○	●	
Dairy Creek	•	⬤	●	◯	●	
Lower Los Osos Creek	•	⬤		◯	●	
Upper Los Osos Creek	•	⬤		◯	•	

◯ — *Highly Limiting,* ○ — *Moderately Limiting,* ◦ – *Minimally Limiting, Blank – Not Limiting, NA – Insufficient information. Closed circles denote where enhancement actions could be effective (see Management Measures – Chapter 3).*

CHAPTER 3 - MANAGEMENT RECOMMENDATIONS

3.1 Introduction

The management recommendations described in this chapter were developed with the goal of improving conditions for steelhead in the Morro Bay watershed. They are based on review of the limiting factors to steelhead trout success identified in Chapter 2 of this report and discussions with CSLRCD staff, the California Department of Fish and Game, staff at the California Mens Colony, and City of Morro Bay staff.

The management recommendations put forth in this chapter are meant to be general, programmatic and watershed-wide. The recommendations should be reviewed and discussed in terms of how each may change or influence current policies, ordinances or programs that apply to the Morro Bay watershed or other stakeholder agencies such as the Department of Fish and Game and National Marine Fisheries Service. In many cases, further study is recommended to determine the feasibility of the enhancement measure in terms of cost, scope, and overall benefit to steelhead populations.

3.2 Streamflow Recommendations

Recommendation SF-1: Establish an unimpaired flow requirement for Chorro Reservoir from May to October. Current release requirements for Chorro Reservoir mandate a minimum 1 cfs release when inflow into the reservoir exceeds 2 cfs. When inflow is less than 2 cfs, the release is only required to be ½ of the total inflow amount. We recommend a complete bypass of baseflow during the low flow period from May to October up to a 4 cfs maximum. Chorro Reservoir fills primarily through winter stormflows and the reservoir spills during most years (12 out of the last 15 year). Allowing unimpaired flow through the reservoir would greatly benefit steelhead populations in Chorro and have only a minor impact on reservoir storage volumes which are highly dependent upon winter storm flow. According to staff at CMC, Camp San Luis Obispo is the only water user in the area that relies solely on Chorro Reservoir water. CMC and Cuesta College have contracts with the State Water Project. During dry years, when Chorro Reservoir water is unavailable, Camp San Luis can arrange to purchase water through the State Water Project. To implement this plan, more rigorous streamflow sampling of tributary inputs to Chorro Reservoir should be investigated. Under the current system, gross errors could occur estimating total inflow into the reservoir.

Recommendation SF-2: Improve watershed protection measures upstream of Chorro Reservoir. If the reservoir is the sole potable water source for Camp San Luis, watershed protection measures should be implemented in the contributing watershed area to reduce erosion and eventual sedimentation of the reservoir. Protection of this existing source of surface water and storage volume in the reservoir would reduce the need to develop additional water storage facilities, improve water quality, and reduce future infrastructure investments.

Recommendation SF-3: Pursue plans for release of reclaimed wastewater into Chorro Creek or tributaries that present a high resource value for steelhead. An existing release just downstream of Cuesta College at the CMC wastewater treatment facility and a proposed release in the same vicinity by the City of Morro Bay could provide a minimum of 1.75 cfs of continuous flow to Chorro Creek and up to an average of 2.6 cfs. This would provide adequate streamflow through Chorro Creek in the summer months to support a high number of rearing steelhead. Unfortunately, the presence of pikeminnow in the mainstem of Chorro Creek limits the benefits of such releases. Another option is to split these releases and discharge them into strategic locations on Dairy and Pennington Creek. An analysis of this potential option should be conducted to determine the initial capital costs of such a scenario and the long-term operating costs that would be incurred due to additional pumping needs. The potential cost of the project could be weighed against the benefit the increased summer streamflow in the Dairy and Pennington would have on steelhead populations in the watershed. DF&G habitat restoration grants or restoration funds through Proposition 12 and 40 could pay for the initial capital costs with operating costs being absorbed by the operators to mitigate impacts elsewhere in the watershed.

Recommendation SF-4: Conduct water supply pumping overnight. Streamflow is often the highest during the nighttime hours as evaporation and transpiration are reduced. This is also the period of time when fish are relatively inactive and not feeding. During the low-flow summer months, water that is being stored off-channel for use during peak demand periods should be diverted during the hours of 9pm and 5am. Municipal water suppliers should assess their operations during low-flow summer months based on this recommendation.

Recommendation SF-5: Establish continuous streamflow monitoring stations on Chorro and Osos Creek. During replacement of a stream crossing at Canet Road, a continuous streamflow monitoring station was removed and has yet to be replaced. This is a problematic trend occurring throughout the United States as federal, local, and state agencies are unwilling to fund long-term monitoring due to fiscal constraints and a perceived notion that the information is not worth the money spent on it (Lanfear and Hirsch, 1999; Rodda, 1998). Though there are plans to replace the Canet Road gage, basic hydrologic information should also be collected on Los Osos Creek. Periodic monitoring of streamflow at sites throughout the watershed by the MBNEP should be continued indefinitely. Though this information may not appear to be immediately valuable, long-term, continuous streamflow records provide a wealth of information about biological conditions and land-use trends, and aid in the development of restoration parameters and modeling parameters.

3.3 Sediment Recommendations

Recommendation S-1: Follow sediment reduction recommendations put forth in Morro Bay TMDL and MBNEP Sediment Source Study. These two studies are nearing completion and include an array of sediment reduction recommendations to reduce fine sediment input into streams of the Morro Bay watershed and ultimately Morro Bay itself. The TMDL is a general document that analyzes sediment input at the watershed scale from different sources, establishes an allowable load into stream channels, and sets streambed condition targets to remove sediment impairment through an upland sediment reduction program (CCRWQCB). The Morro Bay Watershed Enhancement Program continues to provide technical assistance and cost sharing to implement measures to control sediment from agricultural sources. The Sediment Source Study, being funded through the MBNEP, is identifying specific sediment source problems in the watershed and prioritizing each source based on a cost benefit for sediment delivery to Morro Bay. Sediment reduction efforts should focus on sources that chronically input fine grained, impairing sediment to the stream channel.

Recommendation S-2: Repair bank erosion problems through a reduction in channel entrenchment. Many of the streambanks throughout the Morro Bay watershed are unraveling due to channel downcutting and widening (increased channel entrenchment). Many stream channels have historically been straightened and narrowed and impervious surfaces have increase throughout the watershed. The result has been natural channel adjustments to regain lost floodplain area and adjust to higher peak flows. Banks have unraveled, resulting in further loss of riparian vegetation and more instability. We recommend that bank repairs consider floodplain development and reductions in bank angles, rather than attempting to stabilize a transitional situation through toe protection. Newly establish grades are more stable and floodplain benches (whether small or large) can then handle larger flood flows and recruit new riparian vegetation.

Recommendation S-3: Add structural elements to the channel to increase hydraulic complexity. In the Pacific Northwest, large woody debris provides the structural channel elements necessary to form pools and sort fine-grained sediment from spawning gravel. This is primarily accomplished through increases in hydraulic complexity that creates turbulence to move and sort sediment. Though large pieces of wood do not often occur in the Morro Bay watershed, boulders, bedrock outcrops, and streambanks supported by roots act as structural elements to create deep scour pools and sort gravels. In many cases this may only require placing large boulders in strategic places in the channel. This is often a cost effective way of improving rearing habitat while sediment reduction efforts on the hillslopes and streambanks seek to reduce long-term supply. This recommendation should be cross-referenced with *Rearing Habitat Recommendations (Section 3.5)*.

3.4 Passage Barrier Recommendations

Recommendation PB-1: Modify barriers according to the priorities set in Table 2.4. The highest priority barriers identified in the watershed are the Highway 1 culverts at San Luisito (Site #1) and Dairy Creeks (Site #3). San Luisito has the potential to be a very productive steelhead stream due to relatively high baseflows that occur there. Improving passage through this site and just upstream at Adobe Road (Site #2) could greatly increase the amount of easily accessible rearing habitat to adult steelhead. The next highest priority would be the culvert at Highway 1on Dairy Creek. Though streamflow conditions in Dairy Creek are low, adequate pool habitat is available for rearing. In all tributaries to Chorro Creek, improving passage conditions needs to be carefully considered so as not to allow pikeminnow access to the same habitat. A detailed hydraulic study at each site, combined with a good understanding of the physical capabilities of these two species will be vital when designing a repair for each site. It may be better to err on the side of less passage than to allow pikeminnow to expand its current range.

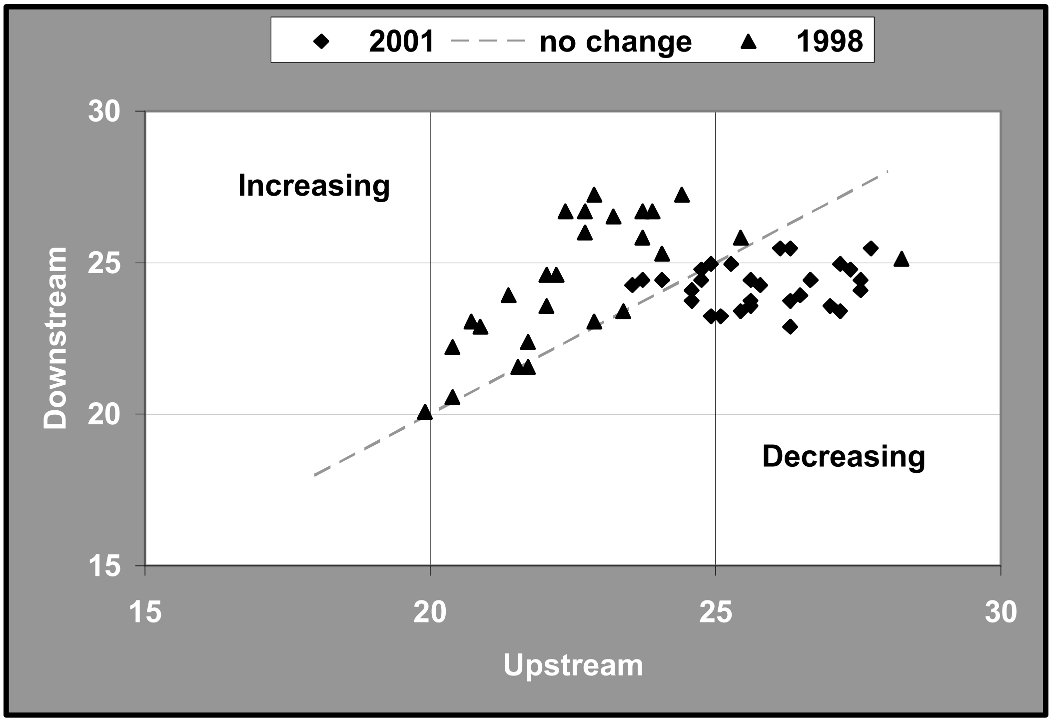
Recommendation PB-2: Where feasible, replace existing undersized culverts with span bridges. In all circumstances, free span bridges are preferable to culverts. Free span bridges improve salmonid passage, allow for the maintenance of a natural channel bOttem, pass debris without continual maintenance, and eliminate instances of mass failure and sedimentation when a culvert and fill prism fail due to clogging or overtopping. Where span bridges are not economical or feasible, use oversized arch culverts or buried round culverts to allow simulation of a natural stream bed through the culvert. All undersized culverts should be replaced and redesigned to handle a 100-year flood with a margin of safety for debris.

3.5 REARING HABITAT RECOMMENDATIONS

Recommendation RH-1: Initiate a study to evaluate the feasibility of eradicating non-native predatory fish from Chorro Creek and Chorro Reservoir. The pikeminnow, and potentially other fish species, limit steelhead juvenile production more than any other factor on the mainstem of Chorro Creek. Though it is a monumental task to completely eradicate them from over ten miles of stream channel and the reservoir, we recommend studying its feasibility. Any plan to eradicate pikeminnow from the watershed should begin with Chorro Reservoir, the assumed source of the pikeminnow. Once eradicated from the reservoir, a program could be started on the mainstem that could include attempts to reduce summer water temperatures to favor steelhead over pikeminnow.

Recommendation RH-2: Restore riparian vegetation canopy through a planting program. Riparian vegetation is one of the most important elements in any functioning stream ecosystem. It provides shade to reduce water temperatures, stabilizes streambanks to reduce erosion, creates habitat through undercut banks, rootwad scour pools, and escape cover from fallen trees, and harbors insects and leafy material that aquatic insects and fish feed from. Planting riparian vegetation is also a very cost effective way to improve habitat. Though it is often labor intensive, it requires minimal pre-planning and can involve volunteers and watershed groups. It can also get the community involved in stream restoration and allow for a forum to educate the public about the value of their stream corridors and the animals that live in it. Revegetation and increases in the riparian canopy along a stream channel can decrease water temperatures significantly over a fairly short distance. In the Chorro Flats Floodplain Restoration Project on Chorro Creek, the new channel, without vegetation, raised summer water temperatures through the reach approximately 2^{o}C (3.6^{o}F). After approximately three years of vegetation regrowth through the project reach, temperatures were 2^{o}C lower than the upstream reach, a shift of 4^{o}C (7.2^{o}F) from an unvegetated to a vegetated condition (Figure 2.4; McEwen, unpublished data).

Figure 2.4: Comparisons of daily maximum water temperatures between same days in August of 1998 and 2001 through the Chorro Flats Floodplain Restoration Project. In 1998, the restored channel was bare of vegetation. In 2001, a moderate amount of vegetation had returned though more benefits will be seen in years to come (McEwen, unpublished data).



Recommendation RH-3: Encourage ranchers to erect exclusion fencing on primary stream channels. Cattle can cause extensive damage to streambanks, young riparian vegetation, and potentially steelhead spawning redds. In addition, cattle spending time in stream channels during hot summer days can cause water quality problems. Off-channel watering troughs may also need to be developed if water sources other than the stream channel are unavailable. Protection of the riparian corridor is vital element in restoring steelhead habitat and maintaining a cold-water fishery in the Morro Bay watershed. Exclusion fencing should be set back a reasonable distance to allow for expansion of narrow riparian corridors damaged by past encroachment. The Morro Bay Watershed Enhancement Program currently provides assistance and a cost-share program to farmers to erect exclusion fencing. Such programs should be encouraged and expanded in vital steelhead bearing streams in the Morro Bay watershed.

Recommendation RH-4: Research the feasibility of cooling the effluent from CMC's Wastewater Treatment Facility (WTF). High water temperatures in Chorro Creek contribute to the proliferation of pikeminnow throughout the system. Any reductions in water temperature below the recommended threshold of 20°C will improve conditions for steelhead juveniles. Water temperatures measured downstream of the WTF outfall are often 1-2°C higher than water temperatures just upstream. We recommend researching the feasibility of installing cooling towers at the WTF to reduce the effluent temperature to no greater than 18°C. The wastewater treatment facility operated by the City of San Luis

Obispo currently cools their effluent before release into San Luis Creek (Doug Marks, personal communication). Though the actual capital costs are not directly known, an estimate put them at approximately $60,000 to install a single cooling tower at the CMC WTF. According to Mr. Marks, the actual operating costs for the cooling tower are insignificant compared to the cost of the other operations at the plant. This appears to be a feasible option for the WTF if capital costs can be covered through a DFG, Proposition 12, or Proposition 40 grant. Lowering the effluent temperature, especially in the summer months would provide a significant benefit to steelhead juveniles in Chorro Creek. If this is combined with an effort to discharge into Pennington or Dairy Creeks, significant, immediate improvements can be made to steelhead populations in the Morro Bay watershed.

Recommendation RH-5: Large woody material should be retained, not removed, in all streams, where feasible. Woody material is often removed from stream channels or cut into smaller pieces through both public and private effort because of the potential flood control, erosion, and property damage issues. Because wood is an important feature in developing good steelhead rearing and spawning habitat, attempts should be made to retain wood that is recruited to the channel at suitable locations where such material would not contribute to a threat to life and property. In limited cases, large woody material jams can result in fish passage barriers. In these cases, the debris jam should be modified to allow passage but should not be removed. Woody material should also be included in stream restoration or bank repair projects along with other roughness elements such as boulders (*cross-reference to Recommendation S-3*).

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