APPENDIX 1: DEMONSTRATION OF AN INTEGRATED WATERSHED ASSESSMENT USING THE LEVEL 1, 2, 3 MONITORING FRAMEWORK IN THE MORRO BAY WATERSHED

Demonstration of an Integrated Watershed Assessment using the Level 1, 2, 3 Monitoring Framework in the Morro Bay Watershed

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LIST OF ACRONYMS

CCWGIS Central Coast Wetlands Geographic Information Systems Project
CCWG Central Coast Wetlands Group
CRAM California Rapid Assessment Method
CSLRCD Coastal San Luis Resource Conservation District
EMAP Environmental Monitoring and Assessment Program
NWI National Wetlands Inventory
RMC Los Angeles and San Gabriel Rivers and Mountains Conservancy
SAP Science Advisory Panel (of the Wetlands Recovery Project)
SCCWRP Southern California Coastal Water Research Partnership
SWAMP Surface Water Ambient Monitoring Program
TIGER Topologically Integrated Geographic Encoding and Referencing System
USACOE United States Army Corps of Engineers
USEPA United States Environmental Protection Agency
MBNEP Morro Bay National Estuary Program
MBVMP Morro Bay Volunteer Monitoring Programs
IEP Implementation Effectiveness Program
VMP Volunteer Monitoring Program

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ABSTRACT

Aquatic resource management depends on a comprehensive understanding of watershed condition. Unfortunately most monitoring and assessment is based on a single objective (e.g. regulatory compliance) or a single indicator (e.g. benthic macroinvertebrates). To remedy this, the USEPA has proposed a three-level framework for wetland monitoring. Level 1 evaluates extent and distribution (i.e. inventory); Level 2 assesses regional condition; and Level 3 conducts detailed or site-specific evaluation.   This integrated assessment approach was demonstrated in the Morro Bay Watershed, near San Luis Obispo, California using a series of wetland assessment tools developed by the state over the past five years. Demonstration of the three-tiered assessment in the Morro Bay watershed achieved three goals: 1) A synopsis of the extent and geographic distribution of the riverine wetlands and their associated riparian areas in the Morro Bay Watershed, 2) a probability-based survey of the ambient condition of the riverine wetlands and their associated riparian areas, and 3) an assessment of the status of a set of riverine restoration projects relative to the watershed ambient picture.

An analysis of land use within the Morro Bay watershed revealed that the watershed is comprised of more than half agricultural land, primarily rangeland, with only 20 percent designated as open space. Over 2,000 acres of contemporary wetlands and riparian habitat were mapped in the Morro Bay watershed. Riverine and riparian wetlands make up 31 and 25 percent of the wetlands respectively, with palustrine wetlands creating 24 percent of the wetlands. The ambient assessments revealed that 29 percent of the wetlands are in excellent condition and 61 percent of the wetlands are in good condition. Land use and watershed position showed a significant affect on CRAM index score (p=0.05). The assessments of the restoration projects revealed a wide range of CRAM index scores from 48 to 92. The comparison of ambient CRAM index scores to the statewide average revealed similar percentages of wetlands in excellent condition, whereas the ambient assessments have a greater percentage in good condition compared to the statewide average (61% and 34 % respectively). Morro Bay watershed has a greater amount of stream length in excellent and good condition compared to the statewide average (90% compared with 50% statewide).

Wetlands and riparian habitat were mapped using the Morro Bay wetland and riparian data set created by the CCWGIS project (Level 1). Ambient condition was determined via probabilistic sampling using the California Rapid Assessment Method (CRAM). Condition at specific restoration project sites were also evaluated using CRAM. The resultant data provided a multi-metric evaluation of wetland extent and ambient condition, while providing a context to interpret condition at project sites and to identify priority needs for future analysis.

Keywords: wetland monitoring, level 1-2-3, three-tiered assessment, CRAM, ambient monitoring, project monitoring, Morro Bay, GIS

INTRODUCTION

A comprehensive regional monitoring program is critical to the recovery of wetland ecosystems that have been dramatically lost, altered, or degraded by human activities over the past 150 years. Effective aquatic resource management depends on an in-depth understanding of watershed condition; therefore, a successful monitoring program requires the incorporation of information on current and/or historical impacts to wetlands, ambient condition, the effect of anthropogenic stressors, and the progress of restoration projects. The effective synthesis of this information forms the scientific basis upon which to base policy decisions for sustainable management of these resources.

Unfortunately, most current watershed monitoring and assessment is based on a single objective or a single indicator, thus a comprehensive perspective of the wetland condition is not possible. For example, historical wetland loss and degradation are often cited as rationale for management actions (e.g. wetland acquisition, restoration, and creation), but information on historical impacts is often limited to estimates of change in area over a specific point in time and data on changes in habitat condition are lacking. Likewise, wetland monitoring is often focused on specific projects or sites, but information on overall ambient condition, necessary to supply the ecological context for project-based assessments, is often not available. Ultimately, resource managers need to integrate data at both the ambient and project levels in terms of change to both wetland acreage and condition to make informed management decisions.

Recognizing this disconnect, a consortium of scientists and managers in California began developing a wetland monitoring and assessment program in 2003 to facilitate integration of statewide monitoring and assessment data. This program is modeled after the U.S. Environmental Protection Agency's (USEPA) Level 1-2-3 framework for monitoring and assessment of wetland resources (USEPA, 2006); Level 1 evaluates wetland extent and distribution (i.e. inventory); Level 2 assesses regional condition; and Level 3 conducts detailed or site-specific evaluation. This framework is intended to be applicable to wetlands and associated riparian habitats in their broadest sense to include almost all water body types (lakes, estuaries, lagoons, wadeable streams, rivers, and intertidal/beaches).

In California, a number of associated assessment tools have been developed under the Level 1-2-3 framework as proposed by the USEPA. The application of these tools is intended to provide data to agencies and the general public on wetlands and riparian areas that are appropriate at the specified level of monitoring. These tools include standardized wetland and riparian mapping methodologies, tools to assess stressors on wetlands at a landscape scale, the California Rapid Assessment Method (CRAM) for wetlands, and standardized level 3 monitoring protocols. Implementation of the monitoring toolkit within the Level 1-2-3 framework provides the means for a cost-effective, comprehensive assessment of ambient extent and condition of aquatic resources and beneficial uses. These tools can be applied at the state, region, or watershed scale to inform management actions and prioritize recovery efforts. Stein et al., 2007 provide a complete review of the Level 1-2-3 framework for wetland monitoring and assessment and discusses how it can be integrated in the context of state and federal wetland programs in California.

Although the benefits of applying these tools in programmatic watershed monitoring are recognized, there are relatively few examples of actual implementation e.g. Wardrop, 2007. Therefore, demonstration projects are critical for a number of reasons: they provide proof of concept of the level 1-2-3 framework, they can serve as templates for future applications of the framework, and they provide the basis for iteratively determining how to best integrate multiple levels of information and data into the watershed assessment process.

We demonstrate the application of Level 1-2-3 assessment framework and associated wetland monitoring tools in the Morro Bay watershed (San Luis Obispo County, California). Like many watersheds located in semi-rural regions around the world, wetlands and riparian areas in the Morro Bay basin have been impacted by agriculture, development and other forms of anthropogenic disturbance. This assessment focused on answering a series of priority questions identified by wetland resource managers in the region: What wetland resources exist in the watershed? What condition are they in? How do the management efforts affect the wetlands?

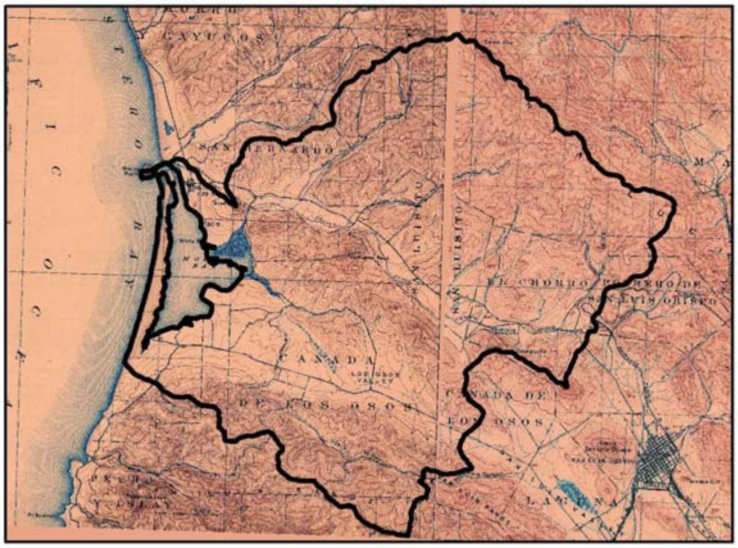
Morro Bay is the most extensive and valuable estuarine/intertidal habitat between Elkhorn Slough and Santa Barbara. However, the bay has lost more than one quarter of its tidal volume in the last 100 years by filling with fluvial transported sediment (Haltiner et al., 1991). There is evidence of up to seven feet of channel aggradation in Chorro Creek and similar amounts in Los Osos Creek (Josselyn et al., 1991). Landuse practices such as cattle grazing and intensive farming, especially in the late 1800's, are the main factors that have lead to this increased transport of sediment from the upper watershed down into the estuary. Attempts have been made to reduce erosion throughout the watershed and transport of sediment into Morro Bay. Examples include the Los Osos Creek Wetland Reserve and the Chorro Flats Enhancement Project. Both were implemented in an effort to reconnect rivers to their floodplain to allow for passive sediment capture (Hecht & Malmon, 2003).

In addition to restoration, multiple stakeholders have been working together within this watershed to coordinate monitoring efforts. Funded by the USEPA's Section 319 (h) of the Clean Water Act, the Central Coast Regional Water Quality Control Board (CCRWQCB) managed the Morro Bay National Monitoring Program, which was an integrated watershed-wide monitoring program that ran from 1992 to 2002. This study involved several public agencies and private individuals, and focused on implementing BMPs aimed at reducing non-point source pollution in the watershed, focusing mainly on Chorro Creek. The program then monitored the effects of the selected BMPs on water and habitat quality along Chorro Creek, established a database of overall water quality at selected sites in the Morro Bay watershed, and prioritized problem areas (McNeill et al., 2002). Another program, the Morro Bay National Estuary Program, is one of 28 National Estuary Programs around the nation funded by the USEPA. The MBNEP is a collaborative organization whose mission statement is to bring citizens, local government, non-profits, agencies, and landowners together to protect and restore the physical, biological, economic, and recreational values of the Morro Bay Estuary. Through this agency, the Morro Bay Volunteer Monitoring Project (MBVMP) has been organized and developed. This project, which began at the conclusion of the Morro Bay National Monitoring Program, gathers and trains citizen volunteers to collect long-term water quality data throughout the watershed. Additionally, the Coastal San Luis Resource Conservation District (CSLRCD) is a major player in the region in being responsible for soil and water conservation work within its boundaries. The CSLRCD is able to work directly with private landowners, which is usually a challenge.

Moreover, this watershed has been the focus of a contemporary wetland mapping/inventory project, the Central Coast Wetland GIS Project (CCWGIS). The Morro Bay watershed was chosen to be the pilot watershed for the development of wetland mapping and data collection protocols. Through collaboration, the California Coastal Commission, California Conservation Corps, and the Morro Bay National Estuary Project accomplished an extensive wetland mapping project of the Morro Bay. These partnerships lead to the creation of the Central Coast Wetland Group (CCWG). These data provided the information necessary to develop a landscape and ecological profile for this watershed.

As a result of these programs and agencies and the data they have collected, Morro Bay offered a unique opportunity to demonstrate application of the level 1-2-3 framework at the watershed scale. Specifically, this demonstration intends to (1) illustrate application of the Level 1-2-3 framework to assess condition of streams and associated riverine habitats at the watershed scale; (2) develop a watershed profile for the Morro Bay watershed that includes a characterization of the range of riverine and associated riparian wetlands; and (3) demonstrate the utility of CRAM for regional ambient assessment and project monitoring. This information can be used to prioritize management and restoration activities, provide context for project and/or site-specific monitoring, and identify possible causal relationships of wetland condition.

Extent of wetlands in the Morro Bay watershed, 1897



Overview of Level 1, 2, 3 Framework and Associated Tools

Level 1 Assessment and Associated Tools

The goal of level 1 wetland inventory is to generate information about landscape or watershed-scale extent, distribution, abundance, and condition of wetlands. Level 1 tools provide an understanding of the mechanisms of previous wetland decline, templates for future restoration, a context for making decisions about allocation of scarce funding, and the sample frame for subsequent probabilistic Level 2 assessments of wetland and riparian condition. Wetland inventories are the primary mechanism through which California can evaluate its “No Net Wetland Loss” policy (Sciences, 2001). Examples of Level 1 assessments include wetland mapping, wetland (acreage) trend analysis conducted by the U.S. Fish and Wildlife Service’s National Wetland Inventory (NWI) and studies of historical ecology.

Level 1 assessment can also serve as the basis for wetland landscape profiles, and watershed profiles. Landscape profiles are a critical tool for restoration, management, mitigation, and cumulative imapct assessment of naturally occuring wetlands (Kentula et al., 2004; Johnson, 2005). A landscape profile and its source data can be used to establish a baseline with which future assessments of net change in wetland acreage can be assessed. They can also play an important role in determining how to prioritize management activities within a watershed.

Level 2 Assessments and Associated Tools

The level 2 habitat assessment consists of rapid, cost-effective field-based diagnostic tools to assess the condition of wetland and riparian areas at the regional scale. They can be used as part of either ambient or project-specific assessments. Level 2 methods provide a single rating or score of overall condition that indicates where a wetland falls on the continuum ranging from full ecological integrity (least impacted condition) to highly degraded (poor condition). For ambient assessments, Level 2 tools provide an evaluation of wetland condition within a population of interest (e.g. specific geographic area, particular wetland type). Level 2 tools can also be used to evaluate the overall condition of specific wetlands of interest for project evaluation, planning, restoration success, etc. Once verified with Level 3 site intensive assessments, rapid assessment methods can be used to support regulatory decision-making and local land and water use planning.

In California, the USEPA funded the development of the California Rapid Assessment Method (CRAM) as a Level 2 tool designed for routine use in local, regional, and statewide programs to monitor wetlands and riparian areas (Collins et al., 2007). CRAM provides an assessment of overall ecological condition in terms of four attributes: landscape context, hydrology, physical structure, and biological structure and also includes an assessment of key stressors that may be affecting wetland condition. The overall goal of CRAM is to provide a rapid, scientifically defensible, and repeatable assessment methodology that can be used routinely in wetland monitoring and assessment programs. It is intended that CRAM be applicable to wetlands and riparian areas throughout the state of California and provide a consistent monitoring approach without neglecting characteristic differences in wetland form or function between regions or between types of wetlands. CRAM has been calibrated for all wetland classes and validated against independent, Level 3 measures of condition for estuarine and riverine wetlands (Stein et al., *in review*).

Level 3 Assessments and Associated Tools

Level 3 assessments consist of detailed evaluations of wetland condition, mechanisms and processes, and stressors at specific locations. Level 3 assessments are the most commonly conducted form of monitoring. Relying mostly on field-based methods, level 3 assessments produce higher resolution and detailed results than typically obtained by levels 1 and 2. However, because of the expense, the information is usually collected at fewer sites and is more difficult to extrapolate to the regional scale.

Level 3 metrics are robust and produce information that can be used to refine rapid assessment methods based on a characterization of reference condition, diagnose the causes of wetland degradation, develop design and performance standards for wetland restoration, including compensatory wetland mitigation, and support the promulgation of water quality standards that are protective of wetlands. Wetland bioassessment procedures and indices of biotic integrity (IBIs) are often developed and used in Level 3 assessments. Other examples of Level 3-type monitoring include data collected pre- and post-restoration, focused species studies related to academic research, and monitoring performed as a part of management plans for federal and state protected lands.

In the Morro Bay watershed, level 3 data were collected by the Morro Bay National Estuary Program (MBNEP) in association with their Implementation Effectiveness

Program (IEP) and Volunteer Monitoring Program (VMP). Monitoring was throughout the Morro Bay Watershed to track both ambient water quality trends and the outcome of specific implementation projects. The program currently operates under a state issued grant from the Proposition 50 Coastal Nonpoint Source Pollution Control Program funds (Kitajima, 2008). Data from target sites of the IEP and VPM were used to determine conditions at various locations in the Morro Bay watershed. This was done by comparing data values at the targeted sites to the ambient condition of the watershed.

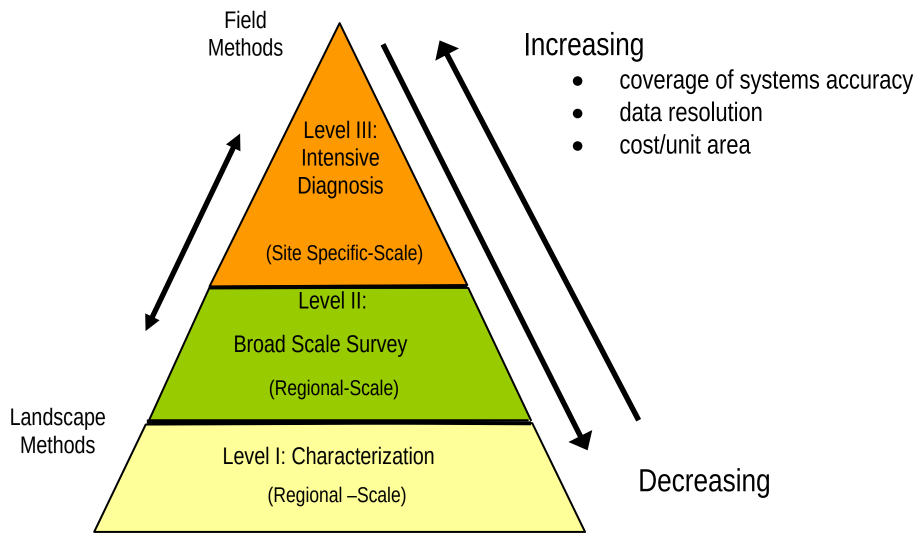


Figure 1. EPA’s Level 1-2-3 Pyramid

METHODS

Description of Study Area

The Morro Bay Watershed is located in the southern part of the Central Coast of California, about 140 miles south of the Monterey Bay (Figure 2). The 48,000 acre watershed is comprised of two sub-watersheds, Chorro and Los Osos. The main stem of Chorro Creek has six main tributaries; San Bernardo Creek, San Luisito Creek, Walters Creek, Pennington Creek, Dairy Creek, and Upper Chorro Creek. The main tributary to Los Osos Creek is Warden Creek. A line of morros called the “seven sisters” separates the two watersheds. The morros are part of a string of fourteen volcanic plugs - eroded Miocene volcanic necks. The original volcanic shell has eroded away leaving the lava that congealed in the neck of the volcanoes. The San Luis Obispo area is comprised mostly of Franciscan complex and serpentine (Norris & Webb, 1990).

The headwaters of Chorro Creek originate at 730 m elevation in the Los Padres National Forest, 5 miles north of the city of San Luis Obispo. There is a dam below the confluence of the three main forks of the Chorro Creek headwaters, and from there it flows westerly for 8.5 miles, paralleling HWY 1 before entering the bay. The uppermost portion of Los Osos Creek originates at 340 m elevation, 6 miles west of San Luis Obispo and flows in the same direction as Chorro Creek for 7 miles flowing next to the town of Baywood-Los Osos before entering into Morro Bay.

The Morro Bay watershed consists of open space, rangeland, military land, private property, and urban areas. The upper watershed of the Chorro drainage is the southern portion of the Santa Lucia Range in the Los Padres National Forest. The mid watershed is characterized by hills of rangeland, primarily vegetated by non-native annual grasses. The lower watershed is a mixture of agriculture, rangeland, recreational, and the Camp SLO military base. The upper and mid portion of the Los Osos watershed is private property. The lower watershed is a mixture of agriculture, rangeland and urban areas.

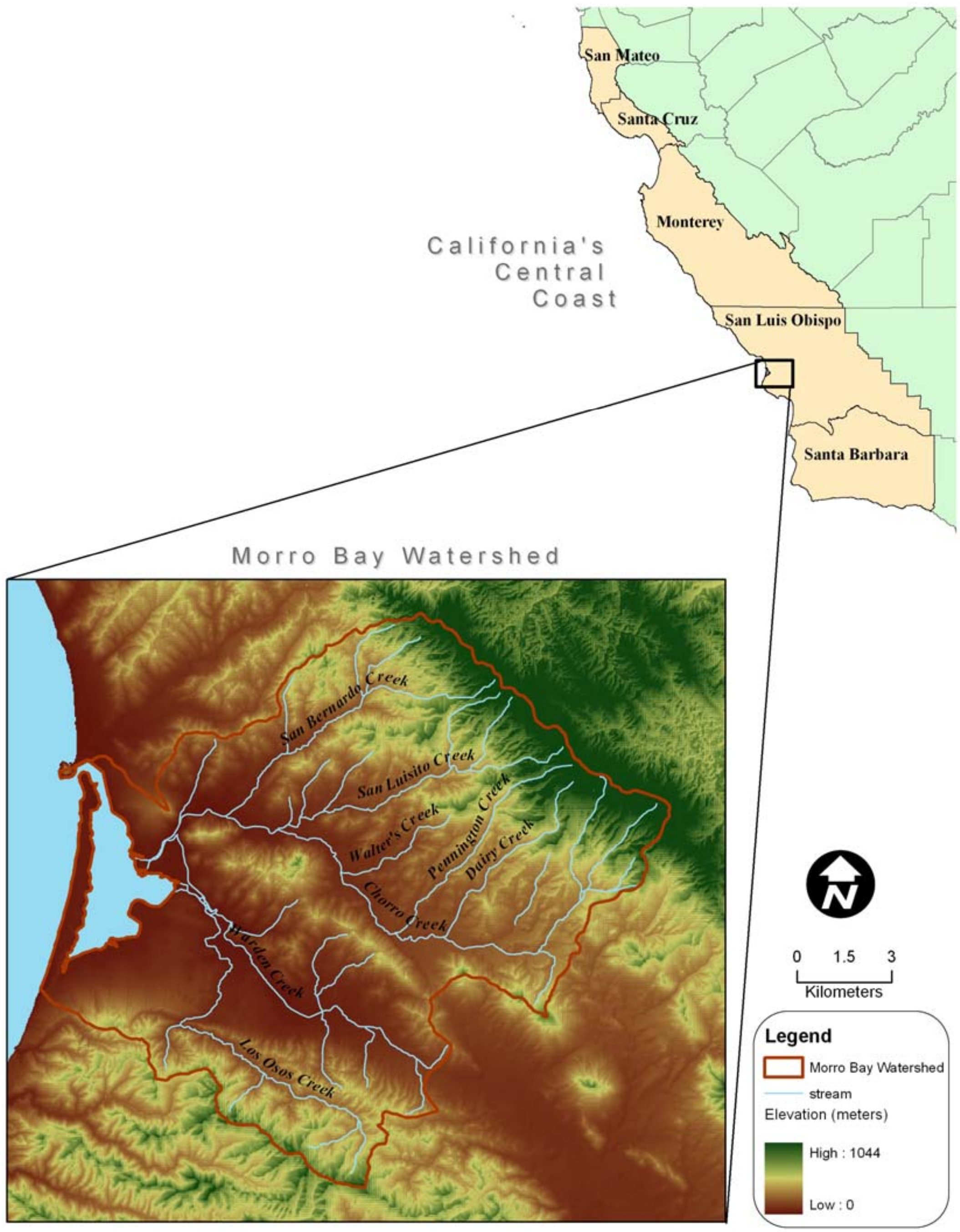


Figure 2. Location of the Morro Bay watershed in relation to the Central Coast of California

Level 1: Landscape Assessment

Wetland/Riparian Habitat Inventory and Mapping

Current wetland maps and standardized wetland and riparian mapping methodologies, supplemented with tools to assess landscape stressors, were used to develop a wetland landscape profile for the Morro Bay watershed. This profile summarizes the extent and distribution of wetlands and riparian areas by wetland habitat type at the watershed scale.

The Morro Bay Watershed Wetland and Riparian Dataset, the most current map of wetlands in the study area, was created by the California Conservation Corps (CCC) and the Morro Bay National Estuary Program (MBNEP). This collaboration supported the first project of the Central Coast Wetland Working Group (CCWWG) in the creation of the Central Coast Wetlands GIS Project (CCWGIS) funded by the USEPA. Wetlands were mapped using aerial photography interpretation and field mapping. Existing datasets for the bay, Chorro Creek, and watershed streams supplemented this work. All wetlands were classified using Wetlands of the Central and Southern California Coast and Coastal Watersheds: A Methodology for their Classification and Description (Ferren Jr. et al., 1995), which used a modified Cowardin approach (Cowardin, 1979). The Cowardin classification of wetlands is a hierarchical classification process with systems (Marine, Estuarine, Riverine, Lacustrine and Palustrine), subsystems (includes deepwater habitats), and more detailed classes, subclasses and dominance types.

Aerial photography interpretation was performed using ArcGIS 8.3. The wetlands were heads up digitized from 2003 orthophotography using a minimum mapping unit of 0.25 acres. Contact prints from June, 2001 supplemented the 2003 photography since 2001 was a wetter year and the intent of the dataset was to capture all wetlands. The Morro Bay streams dataset was used as a starting point for all creeks, except Chorro Creek. The lines were buffered and edited to reflect the creeks depicted on the aerial photography. The Chorro Creek Habitat Typing dataset formed the basis for the Chorro Creek delineation. The bay and salt marsh were mapped as part of the USACOE Feasibility Study and the polygons were incorporated into the dataset and reclassified using the previously mentioned methodology. The ground-truthing and field mapping were conducted by the California Conservation Corps GIS team. Ground truthing was performed in lower and upper Los Osos Creek, Chorro Creek estuarine/riverine transition, and other problem areas throughout the watershed. This consisted of checking the gross delineation of the area and attribution. Field mapping was conducted for the Chorro Creek Ecological Reserve, a portion of Sharks Inlet, and Walters Creek. Wetland delineations were mapped with a minimum mapping unit of 0.10 acre. All ground truthing and field mapping was conducted with a sub-meter GPS and the results superseded the aerial photo interpretation conducted for those areas (CCWGIS, 2004).

The information on the extent and distribution of wetlands and riparian areas by habitat type was summarized to produce a wetland landscape profile for the Morro Bay watershed. The results are displayed as histograms showing amount of wetland and riparian habitat acreage for the watershed as a whole and by sub watershed.

Assessment of Landscape Stressors on Wetlands and Riparian Areas

Maps for the Morro Bay watershed were produced using three types of data: land cover, percent impervious surface, and population density distribution. These maps were used to visually depict land cover in the watershed as well as for context in the assessment stressors that potentially influence riverine wetland condition at the landscape-scale. The land cover map was generated from the National Land Cover Database (NLCD 2000). Percent impervious surface was based on the land cover imagery with values representing the percent of impervious surface within each cell of the raster image (30 x 30 m). The population data was generated from Topologically Integrated Geographic Encoding and Referencing System (TIGER) census data. Land use in the Morro bay watershed was presented using data collected and summarized from the San Luis Obispo countywide landuse categories (2008) shapefile available from the California Polytechnic State University Library.

Level 2: Rapid Assessment of Riverine Wetland Condition

Ambient Watershed Assessment with CRAM

Thirty one randomly selected areas of the Morro Bay watershed were monitored and the ambient riverine and associated riparian wetland condition was assessed using the California Rapid Assessment Method (CRAM). Assessment areas were determined using the recommended size guidelines for riverine wetlands (Collins et al., 2007). In all cases, both sides of the stream channel were assessed. One hundred twenty one points were probabalistically selected using the sample frame developed as part of the Level 1 assessment. The sample draw was weighted by proportion of watershed area to ensure adequate distribution of sites throughout the two main portions of the watershed: Los Osos Creek and Chorro Creek. Potential sites were rejected if they could not be legally or safely accessed. If a site was rejected it was replaced with the next sequential site from the sample draw. The assessments occurred over a six-month period during the summer and fall of 2007 (Figure 4).

More than 90 percent of the Los Osos watershed is private land, whereas Chorro Creek watershed is about 40 percent private land. This presented a serious challenge to gain access to conduct assessments. Permission was granted by two landowners within the Los Osos watershed. Therefore, the Los Osos watershed is not well represented. We were granted access by four landowners within the Chorro Creek watershed and were able to sample the remaining random points on public lands. Camp SLO was particularly helpful in providing access and safe clearance during military operations. In addition, the Regional Water Quality Control Board (Region 3) was helpful in assisting us to gain access for riverine assessments.

As part of the CRAM protocol, the stressor checklists were used to determine the types and number of watershed landuse practices that might influence the CRAM index and attribute score(s). The stressor checklist is completed onsite based on visual clues, and aerial imagery. For analyses the stressors are either present (assigned a value of one), or significant and likely to have a negative impact (assigned a value of two). The values for each assessment were summed to create a total value of stressors for that location. These data were then used to look at major stressors affecting the ambient condition at the CRAM index and attribute level.

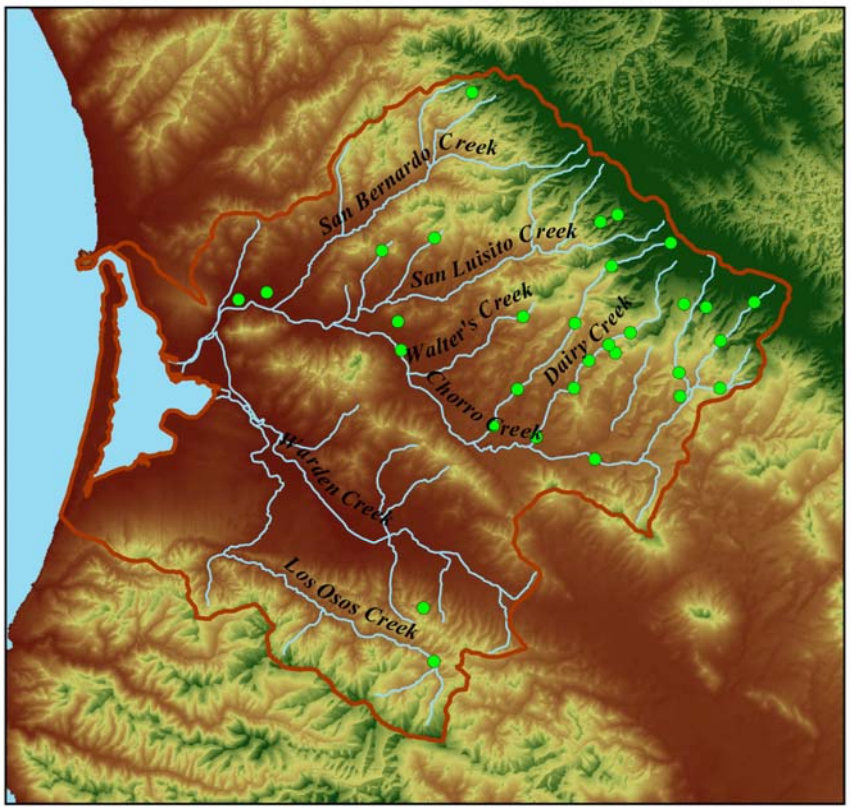


Figure 3. Location of the 30 randomly selected sites sampled in 2007 ambient assessment for the Morro Bay watershed

For analysis, the CRAM index scores were utilized to represent condition in the watershed by classifying ranges of scores. The index scores were binned into equal quartiles with the lowest CRAM score possible being 25 and the highest 100. In the case of this report, any CRAM score in the fair or poor condition were referred to as having sub-optimal condition (Table 1). These scores were then compared to the ambient condition of riverine wetlands across the entire state. CRAM data on riverine wetlands in the entire state were collected at California Fish and Game Perennial Stream Assessment sites in during the summers of 2007 and 2008.

Table 1. Ranges of CRAM scores in relation to classification of condition

Condition	CRAM score range
Excellent	100-82
Good	81-63
Fair	62-44
Poor	43-25

To look at the effect of landscape stressors and landuse on ambient CRAM scores, sites were binned according to watershed position, adjacent land use, adjacent vegetation type and land ownership. A non-parametric Kruskal-Wallis test was then used to look at differences among groups.

Restoration Project Assessment with CRAM

CRAM was used to evaluate the riverine wetland and associated riparian habitat condition at fourteen restoration project sites distributed throughout the Morro Bay watershed during the summers of 2007 and 2008 (Figure 4, Table 2). The fourteen sites were identified and selected based on input from various public agencies operating within the watershed and represented a range of project types (i.e. restoration, enhancement). All projects were completed prior to the CRAM assessment being conducted (Table 2). Assessment areas were determined using the recommended size guidelines for riverine wetlands (Collins et al., 2007). In all cases, both sides of the stream channel were assessed with CRAM. See Appendix 1 for additional information on the project sites.

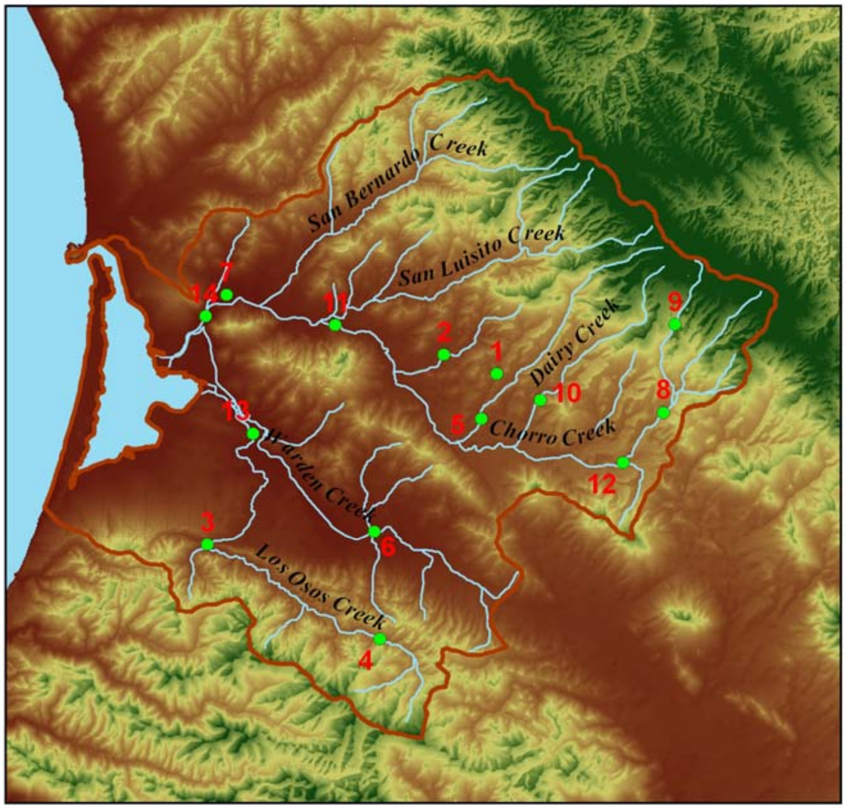


Figure 4. Location of the fourteen project sites assessed with CRAM in the Morro Bay watershed.

Table 2. The fourteen projects assessed during the summers of 2007 & 2008 using CRAM in the Morro Bay Watershed along with location data and actions taken during restoration

Site Number	Project Name	Location (lat., long.)	Action taken
1	Chumash Creek	35.34224, -120.74012	Cattle exclusion fencing, riparian planting
2	Walter's Creek Phase II	35.34654, -120.75616	Cattle exclusion fencing Bank stabilization, riparian planting, fish passage enhancement, stream widening
3	Los Osos Creek-Morrissey Property	35.29821, -120.82540	Bank stabilization, riparian planting
4	Upper Los Osos Creek	35.27610, -120.77300	Bank stabilization, pool creation, riparian planting
5	Pennington Creek	35.33115, -120.74447	Cattle exclusion fencing, riparian planting, bank stabilization
6	Warden Creek	35.30256, -120.77554	Bridge replacement
7	Chorro Creek-Flats	35.35977, -120.82165	Improve steelhead trout summer rearing habitat
8	Chorro Creek-Below dam	35.33389, -120.68996	Cattle exclusion fencing
9	Chorro Creek-Chromium Mine	35.35548, -120.68719	Rock slope protection to prevent erosion
10	Dairy Creek	35.33603, -120.72692	Cattle exclusion fencing, riparian planting
11	Chorro Creek-Canet Rd.	35.35313, -120.78891	Bank stabilization
12	Chorro Creek-Camp SLO	35.32121, -120.70158	Cattle exclusion fencing, riparian planting, winterize roads to prevent erosion
13	Los Osos Creek-Wetland reserve	35.32599, -120.81246	Land acquisition, conversion from agriculture
14	Chorro Creek-Morro Bay SP	35.35442, -120.82775	Cape ivy removal

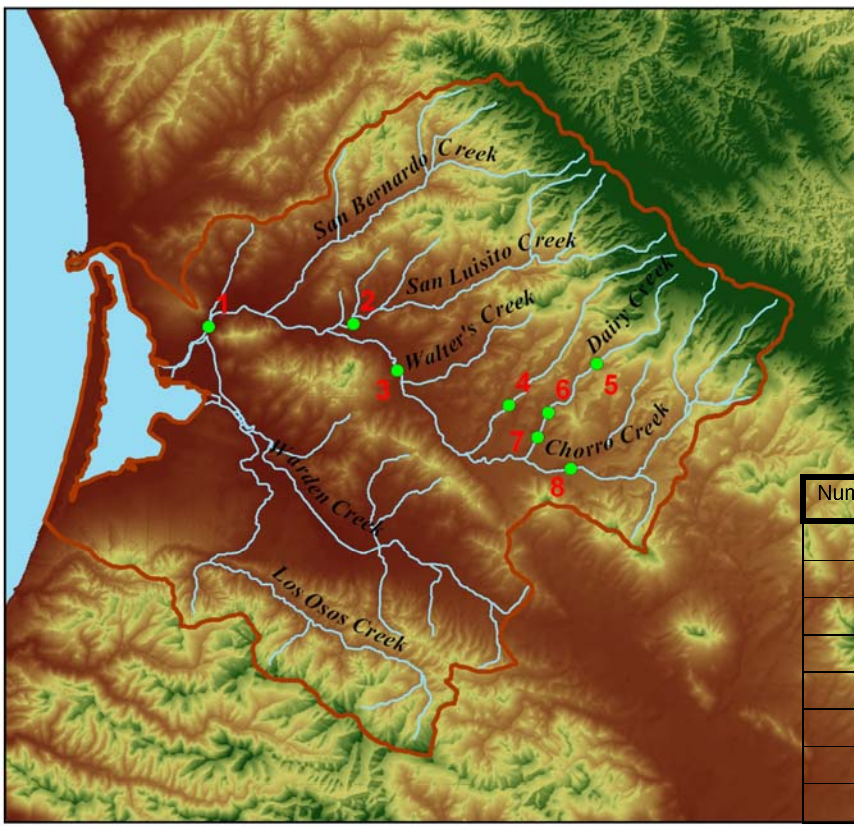
The 2007 ambient survey was used as context to interpret the CRAM metric scores at the restoration project sites. In addition, the CRAM stressor checklist was used to determine the types and number of stressors that could influence CRAM index and attribute scores at the various project sites.

A repeatability analysis previously conducted on CRAM (Stein et al., *in review*) revealed that attribute and overall scores have less than 10% error (out of a total possible score of 100) associated with assessment by different practitioners, and the precision being higher at the attribute level than at the overall index score. Therefore, differences in scores of 10 CRAM points or less are within the error of the method and should not be considered true differences in condition.

Level 3: Intensive Site Assessments

Level-3 monitoring was conducted at sites selected by the MBNEP associated with its Volunteer Monitoring Program (VMP) (Figure 5). The data used in the report represents an average of all samples collected by the VMP from 2002-2007. Water quality data were collected monthly at over 18 sites, however not every site was sampled each month (Kitajima, 2008). Initial training comes from shadowing a trained volunteer or VMP staff member. Occasionally trainings are offered by VMP staff. Additionally, periodic update trainings required. The VMP data were summarized using box and whisker plots to show the median and range of the various parameters.

Comparison of level 2 and 3 data occurred as well; however, the water quality sample locations of the VMP and the ambient assessment CRAM sites of the Morro Bay watershed did not overlap. For each of the VMP water quality sample locations the closest ambient CRAM score was used to compare the water quality parameters (Figure 5). If there was no adjacent ambient CRAM score, the water quality sample location was not analyzed for this report. The MBNEP provides a more complete water quality analysis of the Morro Bay watershed (Kitajima, 2008).



Number	Station Name (MBNEP name)
1	Lower Chorro Creek (TWB)
2	San Luisito Creek (SLU)
3	Middle Chorro Creek (CER)
4	Pennington Creek (PEN)
5	Upper Dairy Creek (DAU)
6	Middle Dairy Creek (DAM)
7	Lower Dairy Creek (DAL)
8	Upper Chorro Creek (CHO)

Figure 5. Location of the eight water quality stations monitored by the Morro Bay NEP Volunteer Monitoring Program from 2002-2007.

RESULTS

The results of this application of the Level 1-2-3 monitoring framework for the Morro Bay watershed are presented in three parts. First, the landscape assessment information is presented (Level-1). This includes present-day wetland mapping, and the land use profile/landscape stressor analysis. The results of the ambient and project-based assessments of riverine wetlands and associated riparian habitats with CRAM are presented separately(Level-2). Finally, the more intensive data (Level-3) including: water quality parameters and nutrients collected by the VMP in 2002-2007 are presented. Correlations among the three levels are also evaluated.

Level 1 – Landscape Assessment

Contemporary Wetland Inventory and Mapping for the Morro Bay Watershed

A total of 2301.25 acres of wetland habitat were mapped in mountain, foothill, valley and intertidal areas of the Morro Bay watershed, containing a wide range of wetland types (Figure 6). The vast majority (79.4%) of wetlands in the Morro Bay watershed are comprised of riverine (708 acres), riparian (573 acres), and palustrine (550 acres) wetlands (Table 2, Figure 7). Of the Palustrine wetlands, most are associated with riverine systesm (e.g. adjacent flood plains) while seeps and springs make up 89 acres. These wetland types are evenly distributed throughout the watershed and present a unique and often isolated aquatic habitat. Estuarine wetlands make up 442 acres of the Morro Bay watershed, fringing much of the bay with most of the acres located on the west end at the confluence of Chorro Creek and Los Osos Creek. A single lacustrine wetland (29 acres) was characterized within the Los Osos Creek sub watershed (Figure 6).

Table 3. The percent composition of wetlands in the Morro Bay Watershed.

Wetland Type	% of Total Wetlands	% of Total Watershed
Riverine	30.7	1.47
Riparian	24.8	1.19
Palustrine	20	1.12
Seeps & Springs	3.9	0.02
Estuarine	19.2	<.10
Lacustrine	1.3	<0.01

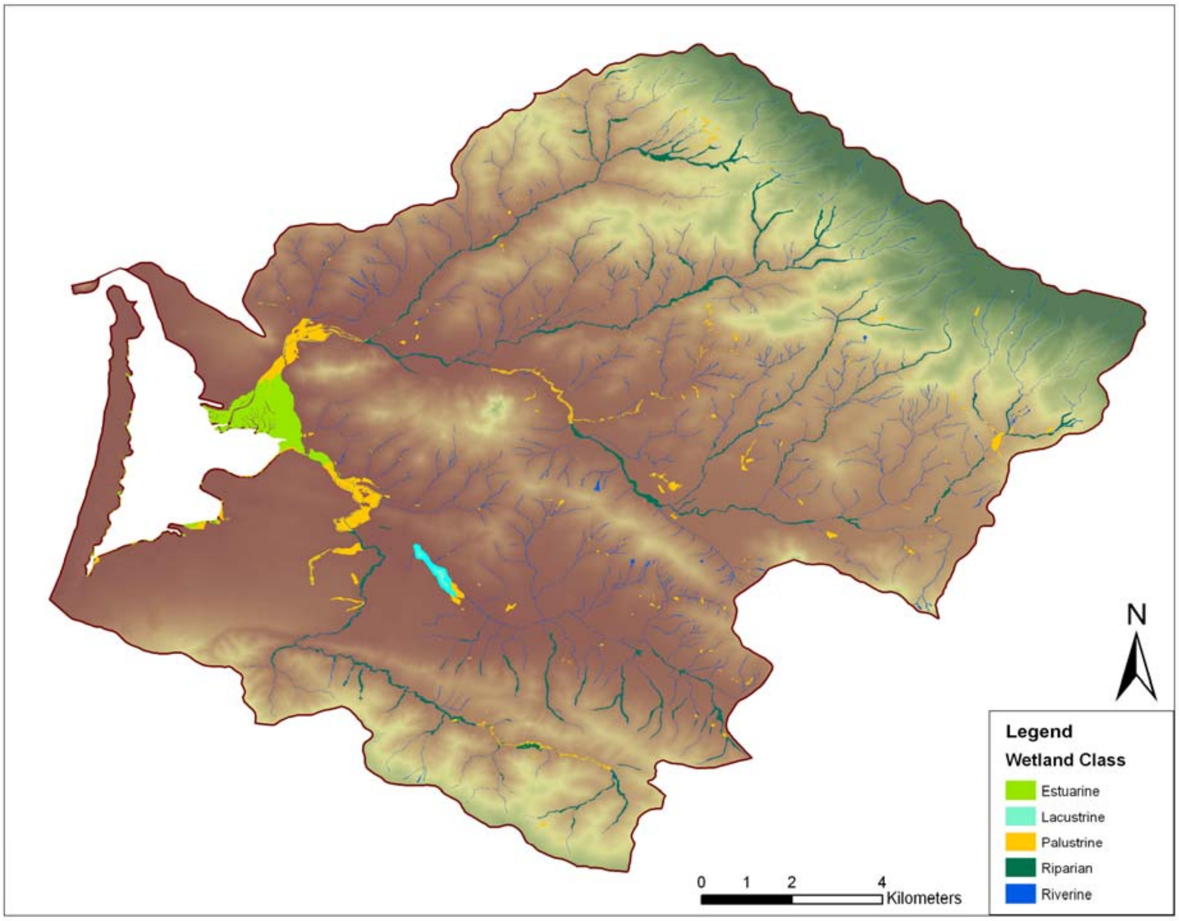


Figure 6. Map of contemporary wetlands of the Morro Bay watershed

The Chorro Creek sub-watershed contains 66.5 percent of the wetlands for the entire watershed. In contrast 31 percent are located in the Los Osos sub-watershed (Figure 7). The remaining 2.5 percent of wetlands are located in the delta between Morro and Estero Bay. An analysis to evaluate the loss of riparian acreage in relation to stream miles revealed that there is no significant difference in the composition of riverine and riparian acreage between the Los Osos and Chorro Creek sub watersheds.

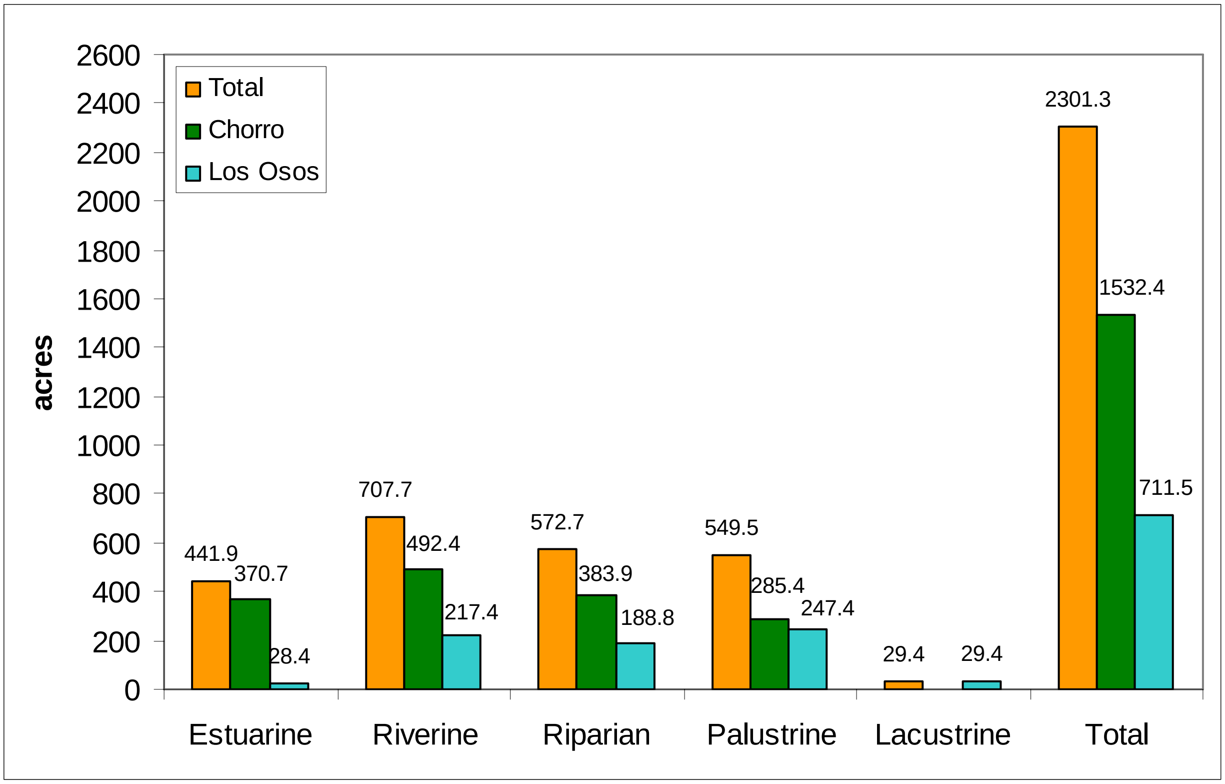
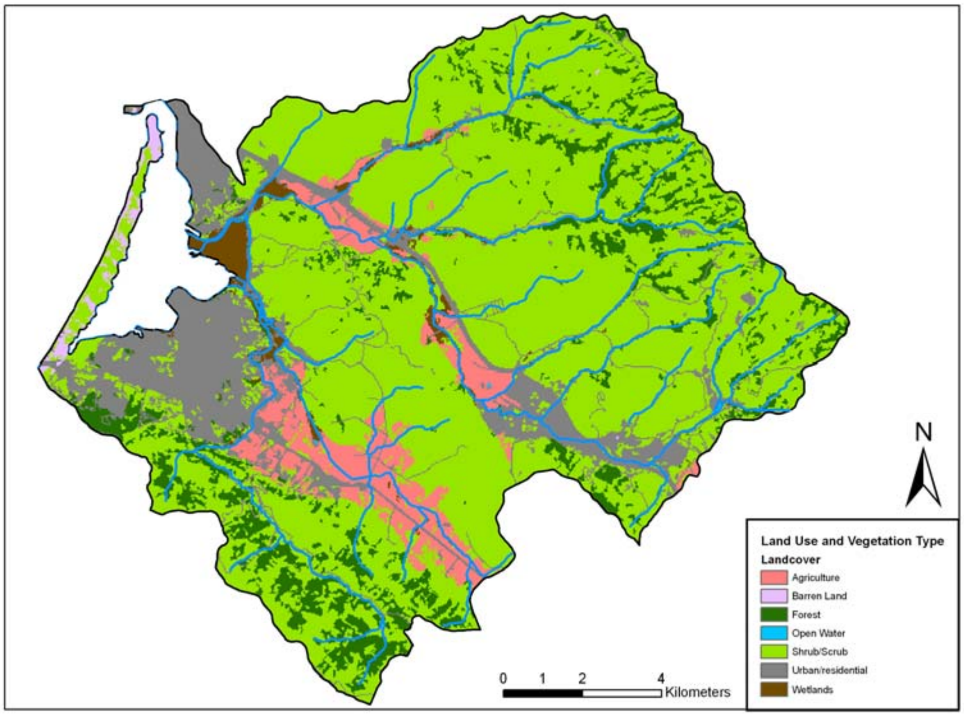


Figure 7. Summary of contemporary wetland acreage in Morro Bay for the full watershed and by subwatershed using a modified Cowardin classification system

Land Use and Landscape Stressors

The primary land cover in the Morro Bay watershed is comprised of shrub/scrub habitat (coastal scrub, chaparral, and non-native grassland). Forested land occurs in the higher elevations of the watershed, and is comprised of oak woodland, chaparral, and juniper. Agricultural land is clustered along the valley floors of Chorro and Los Osos creeks (Figure 8a). Development, as reflected by percent impervious surface, is concentrated in the western, lower elevation portion of the watershed (Figure 8b). Both of these areas are dominated by a mix of urban/residential development and have correspondingly high percentage of impervious surfaces. Little of this impervious surface however flows into the two primary creek systems, but instead is directed to the Bay. In contrast, the entire eastern and southern portions of the watershed within the Santa Lucia Mountains are populated by forest, shrubland, or woodland and are characterized by low percent impervious surface.

a)



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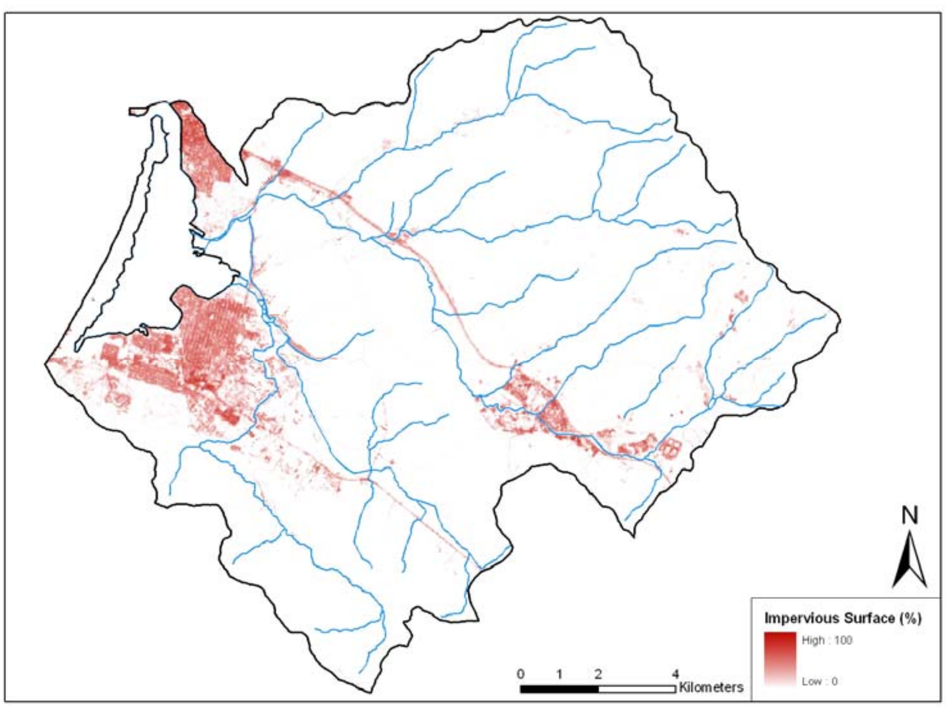


Figure 8. (a) Vegetation/landcover types and (b) percent impervious surface in the Morro Bay watershed.

The land cover results are reflected in the population density data for the Morro Bay watershed (Figure 9). The basin can essentially be divided into two broad segments: the upper three-quarters of the watershed within the Los Padres National Forest, and the Chorro and Los Osos Valleys, with less than 5 people/ acre, and the remaining quarter of urban area near Morro Bay, with higher population densities ranging from 5-100 people/acre. However, the majority of the watershed drainage area and all of our assessment locations were located upstream of the urban areas. As a result the stress on the environment which can come from an urban landscape had little influence on the level 2 and level 3 data that were collected and obtained.

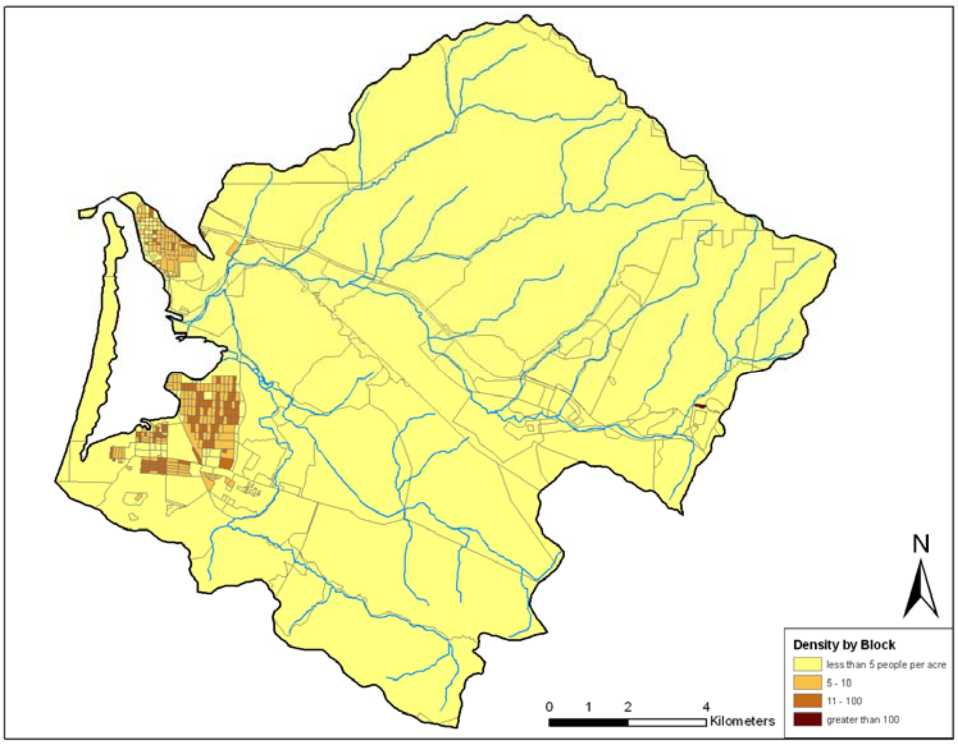


Figure 9. Population density distribution (by block, year 2000 census) in the Morro Bay watershed.

Approximately 57 percent of the watershed has been designated as agricultural use; this is primarily rangeland with some row-crop agriculture in the valley floors. Twenty percent has been set aside as open space or recreational areas, including the Los Padres National Forest. Only 2 percent of the watershed is considered rural land, while the remaining 3 percent is residential area (Figure 10).

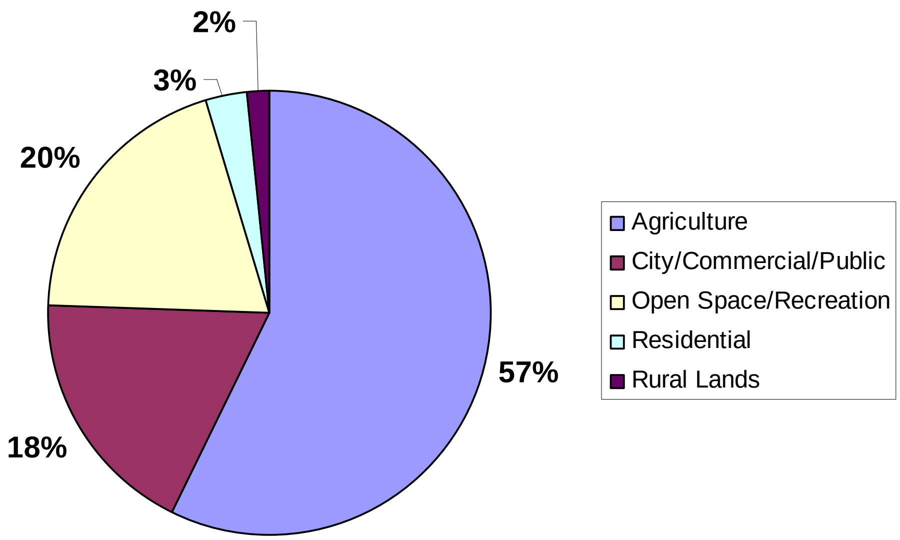


Figure 10. The proportion of landuse types recorded in the Morro Bay Watershed

Level 2 – Rapid Assessment

Morro Bay Ambient Watershed Assessment with CRAM

The results of the 2007 ambient assessment documented a broad range of riverine wetland and associated riparian habitat condition within the Morro Bay watershed. In total, 31 probabilistically selected sites, totaling 27.1 acres in the Morro Bay watershed were assessed. CRAM scores ranged from 43 (with the minimum score possible of 25) to 90 (out of a maximum possible score of 100; Figure 11). CRAM scores were partitioned into score quartile bins to aid comparison of scores among sites. The probabilistic evaluation of wetland condition reveal that 90 percent of the ambient assessment sites are in "good" condition, with 29 percent of those good sites being classified in "excellent" condition. The remaining 10 percent of the ambient assessment sites are in fair and poor condition and considered sub-optimal.

In comparing the ambient riverine condition of Morro Bay to that of a similar probabilistic inventory of wetlands throughout California, Morro Bay was found to have a higher percentage of sites in the "good" and "excellent" than the state as a whole (Figure 11, 90% compared to 63%).

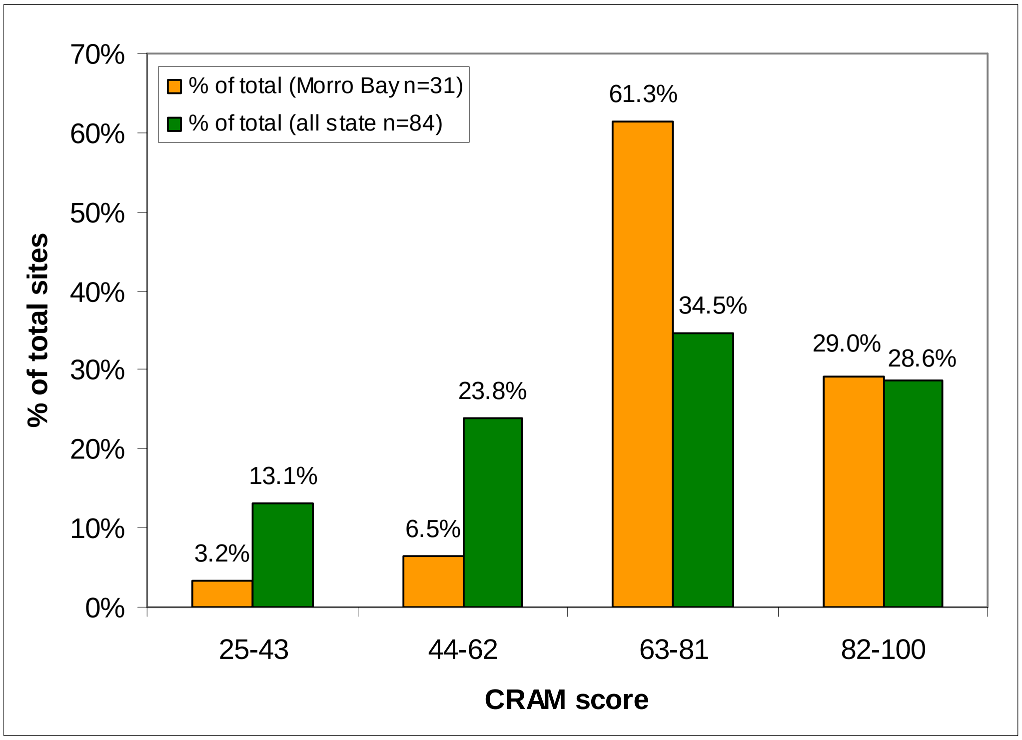


Figure 11. Comparison of the distribution of CRAM scores in the Morro Bay watershed to scores collected across the entire state of California at California Fish and Game Perennial Stream Assessment sites, 2008.

Overall CRAM scores varied by location within the watershed and illustrate clear patterns (p=0.05) between the upper (undeveloped) portions, the middle watershed (rangeland), and lower (more developed) portions in terms of condition (the “all watershed” condition average was added later for reference and not included in the statistical analysis) (Figure 12a). The upper watershed, which is comprised mostly of natural streams on public land, had the highest average CRAM score. The middle portion of the watershed, which is predominantly grazed rangeland, had lower average CRAM scores. The lower watershed, which is comprised of a mix of semi-natural and channelized systems through a mix of urban, agriculture and relatively natural landuse types, had the lowest scores. CRAM scores also varied significantly by adjacent landuse type (p=0.05). Riverine condition at sites located on recreational land (mainly the Los Padres national Forest) and open space had higher scores in general than sites located on rangeland, public facility land (mainly the California Men’s Colony) and on land with row crop agriculture (Figure 12b). Error estimates for CRAM evaluations have been estimated to be +/-10%, which suggest that differences between wetlands are real if not statistically significant as a population.

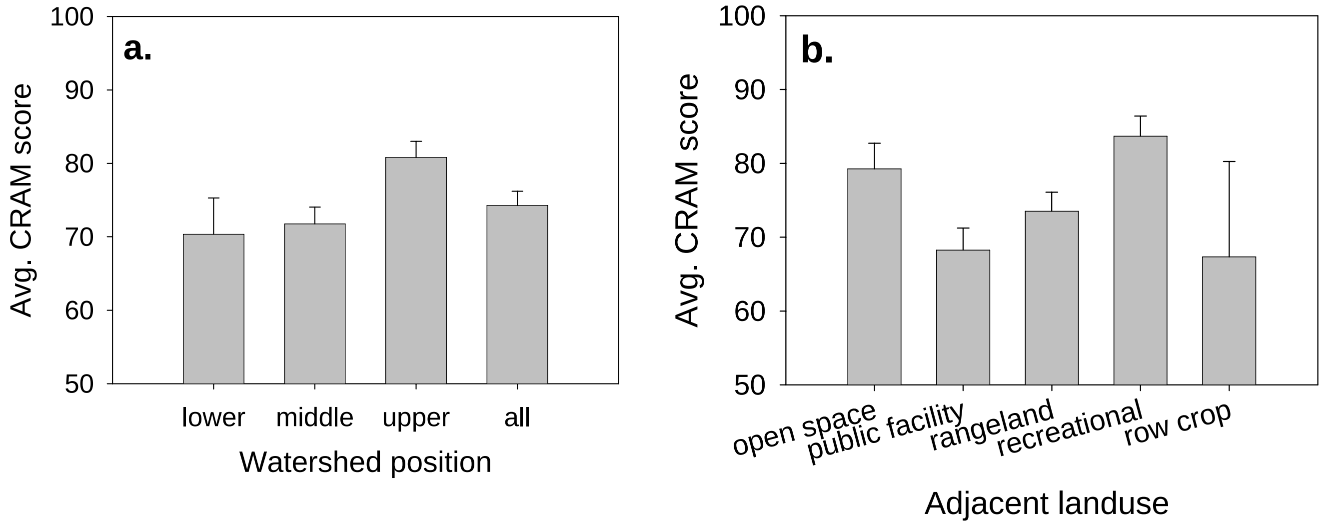


Figure 12. Mean CRAM scores by a) watershed position, and b) adjacent landuse type, bars represent SEM.

Comparing CRAM scores among sites with different adjacent vegetation and land ownership revealed no significant results. However, it showed a trend for higher scores on non-native grassland and riparian vegetation than at sites surrounded by agriculture (Figure 13a). Slightly higher scores were observed on public land than on private (Figure 13b).

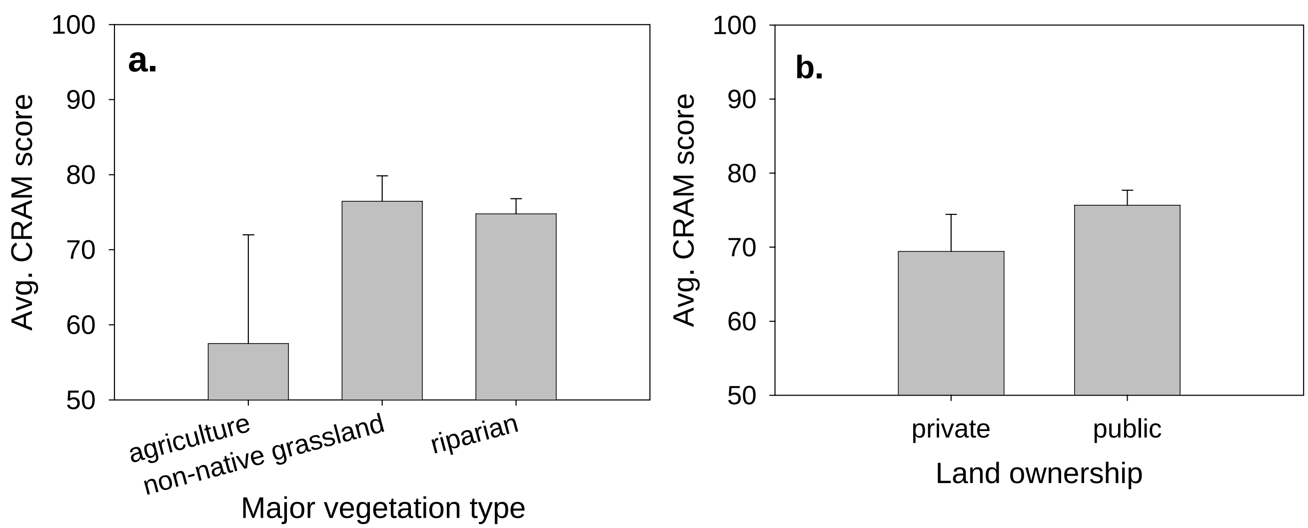


Figure 13. Effect of a) major adjacent vegetation type and b) land ownership on mean CRAM score, bars represent SEM

Landscape Stressors of the Ambient Locations

Analysis of stressors affecting ambient assessment locations showed over half of the ambient sites, 55 percent, had rangeland as a stressor, while 48 percent had military/air traffic present as a stressor, and bacterial impairment was present at 39 percent of sites (Figure 14). Nutrient impairment, mowing/grazing within 50m of the assessment area, and transportation corridor all had a similar occurrence, 32 percent, at the ambient assessment locations.

Rangeland, transportation corridor, and military/air traffic are stressors within the buffer and landscape context attribute. Bacteria impairment and nutrient impairment are within the physical structure attribute, while mowing/grazing is in the biotic structure attribute. This information provided a means to identify site-specific as well as watershed scale management actions.

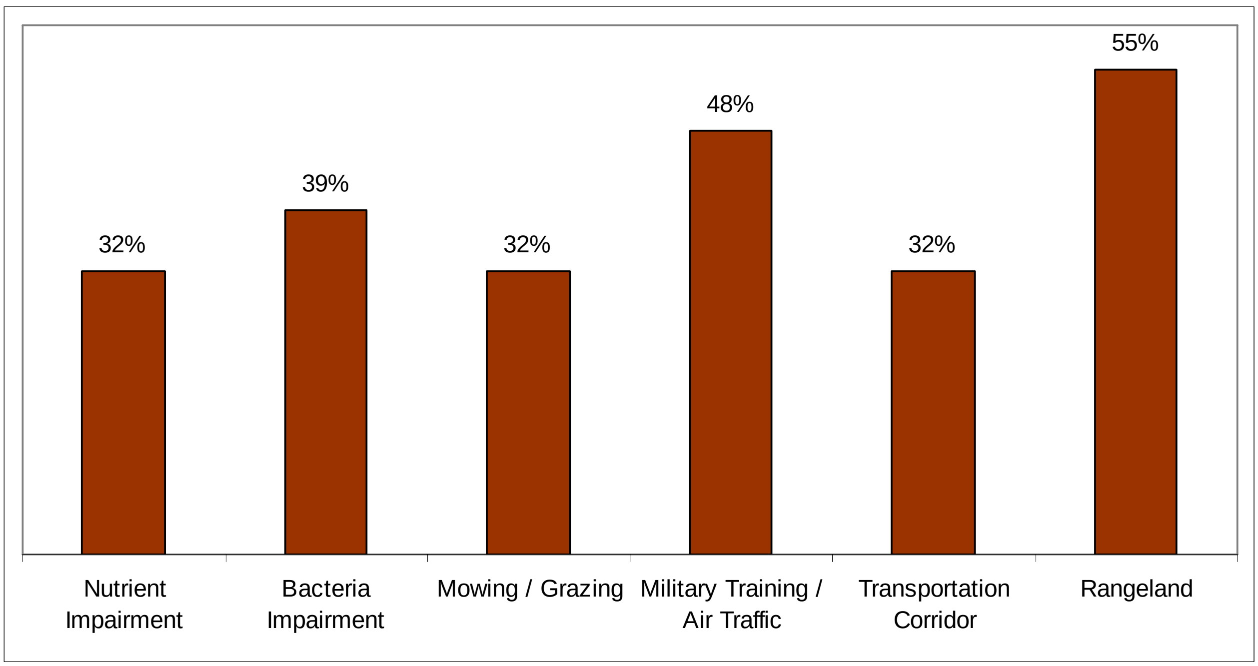


Figure 14. The six most common stressors present at ambient assessment locations with percent of assessments that had the stressor present.

In analyzing the relationship between the condition of an assessment area and the stressors affecting them, it was found that an increase in the total number of stressors (both present and significant) at each site showed to have a significant negative effect on the CRAM score of that site (p=0.001, r^2=0.309) (Figure 15).

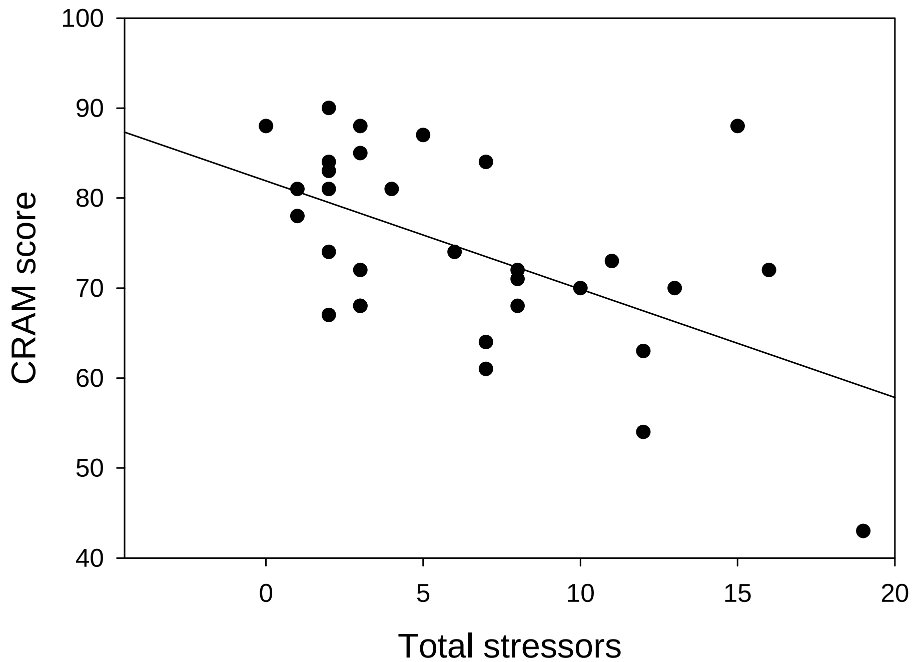


Figure 15. Comparison of total CRAM score to the total number of stressors present at an assessment site.

Taking this analysis a step further to look at the relationship of stressors and CRAM scores at the attribute level, it was revealed that the negative relationship exists for the hydrology (p<0.001, r^2=0.36) attribute, composed primarily of external factors that affect the assessment area (Figure 16). However there was no relationship found between attribute score and the number of attribute stressors affecting the biotic structure and physical structure of an assessment area, both composed of internal metrics affecting the assessment area.

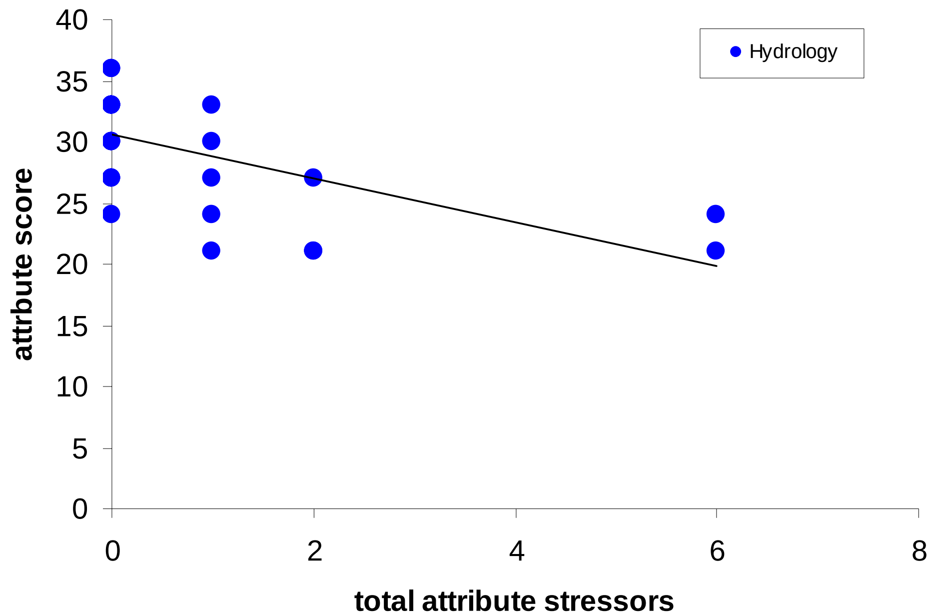


Figure 16. Comparison of the attribute score to the total number of attribute stressors present for the Hydrology at all 31 ambient assessment sites.

Assessment of Restoration Project Sites with CRAM

In 2007 and 2008, a total of fourteen restoration project sites were assessed in the Morro Bay watershed using CRAM, totaling 21.9 acres. Overall CRAM index scores for these restoration sites ranged from 48 to 92 (Table 4). A project completed on Los Osos Creek on the Morrisey Property had the highest overall CRAM index score (92), followed by the Chorro Creek Flats location (87). The project on Warden Creek received the lowest CRAM score (48) and was located in an area of the watershed dominated by intensive row crop agricultue. The other project sites received overall CRAM index scores ranging from 53 to 86. The type of restoration actions taken did not correlate with CRAM scores .

Although overall CRAM index scores for most restoration sites were found to fall in a similar range to the ambient condition assessment for the watershed, the range of attribute level scores for restoration sites differed. In general, sites located in the more agriculturally developed portions of the watershed (e.g. Warden Creek) tended to score lowest for the buffer/landscape context attribute. Conversely, sites located higher up in the watershed scored higher in the hydrology attribute (e.g. Chorro Creek-Chromium mine).

Table 4. CRAM raw attribute and index scores for the fourteen project sites assessed with CRAM in the Morro Bay watershed. Maximum possible for raw attribute scores: Buffer and Landscape Context = 24; Hydrology = 36; Physical Structure = 24; Biotic Structure= 36. Overall index scores range from 25-100.

Site Number	Project Site	Buffer / Landscape	Hydrology	Physical	Biotic	CRAM INDEX Score
1	Chumash Creek	**22**	**30**	**12**	**21**	**71**
2	Walter's Creek Phase II	**22**	**27**	**9**	**16**	**62**
3	Los Osos Creek- Morrissey Property	**24**	**27**	**24**	**35**	**92**
4	Upper Los Osos Creek	**23**	**27**	**21**	**32**	**86**
5	Pennington Creek	**18**	**30**	**18**	**24**	**75**
6	Warden Creek	**15**	**15**	**6**	**22**	**48**
7	Chorro Creek- Flats	**24**	**36**	**21**	**23**	**87**
8	Chorro Creek- Below dam	**13**	**27**	**21**	**31**	**77**
9	Chorro Creek- Chromium mine	**22**	**30**	**15**	**13**	**67**
10	Dairy Creek	**22**	**24**	**15**	**17**	**65**
11	Chorro Creek-Canet Rd.	**19**	**21**	**15**	**21**	**64**
12	Chorro Creek- Camp SLO	**18**	**21**	**12**	**13**	**53**
13	Los Osos Creek- Wetland reserve	**23**	**15**	**9**	**21**	**57**
14	Chorro Creek- Morro Bay SP	**18**	**27**	**15**	**24**	**70**

Landscape Stressors of Restoration Project Locations

Four stressors were commonly noted during the assessment of the project sites in the Morro Bay watershed, including; non-point source discharge, nutrient impairment, transportation corridor, and rangeland. Rangeland and transportation corridor are stressors within the buffer and landscape context attribute within 500 m of the assessment area. The other two stressors, non-point source discharges and nutrient impairment, are within the hydrology and physical structure attribute respectively. This information provided a means to identify site-specific management needs that potentially merit further analysis.

The only two project sites that did not have the four most commonly occurring stressors present were the Morrissey Property on Los Osos Creek and Chorro Creek at the old Chromium mine site. These restoration projects were both bank stabilization projects from serious erosion events. The only two projects to have all four common stressors were Chumash Creek and Upper Los Osos Creek. Both are in rural areas with either cattle grazing or row crop agriculture. Two of the four common stressors however are water quality parameters (noted through use of secondary information found for the drainage) and would not directly effect CRAM scores (other than for the Water Source metric)

Table 5. The four most commonly occurring stressors at each project site

Project Site	Non-point Source Discharges	Nutrient Impaired	Transportation Corridor	Rangeland
Chumash Creek	X	X	X	X
Walter's Creek				X
Los Osos Creek- Morrissey Property				
Upper Los Osos Creek	X	X	X	X
Pennington Creek	X	X	X	
Warden Creek	X	X	X	
Chorro Creek- Flats		X	X	X
Chorro Creek- Below dam		X		X
Chorro Creek- Chromium Mine				
Dairy Creek	X	X		X
Chorro Creek-Canet Rd.	X	X	X	
Chorro Creek- Camp SLO	X	X	X	
Los Osos Creek- Wetland reserve				X
Chorro Creek- Morro Bay SP	X	X	X	

Comparison of Ambient and Restoration Project Level 2 data

Comparison of the metric scores among ambient and project sites for the Morro Bay watershed found differences in average scores for the buffer width, buffer condition, water source, hydroperiod, and topographic complexity metrics (Figure 17). Only the topographic complexity metric had a higher average score in restored areas in comparison to ambient condition. Scores in both restored and ambient sites had lower condition scores than expected for vertical biotic structure, interspersion, and # codominants metrics. Since CRAM was designed to quantify the range of wetland condition throughout the state, these lower scores may be the result of natural limitations in the biotic complexity of rivers in this moderately arid region.

Due to project boundaries and grant limitations, metrics that measure aspects of wetland condition that extend outside the boundaries of the assessment/project area (buffer condition, water source, hydroperiod) are often not addressed in restoration projects. Many of these restoration sites had lower scores for these metrics than at the ambient locations. Conversely, metrics that are usually addressed during restoration (invasive species, plant layers, structural patches) resulted in similar scores among project and ambient sites.

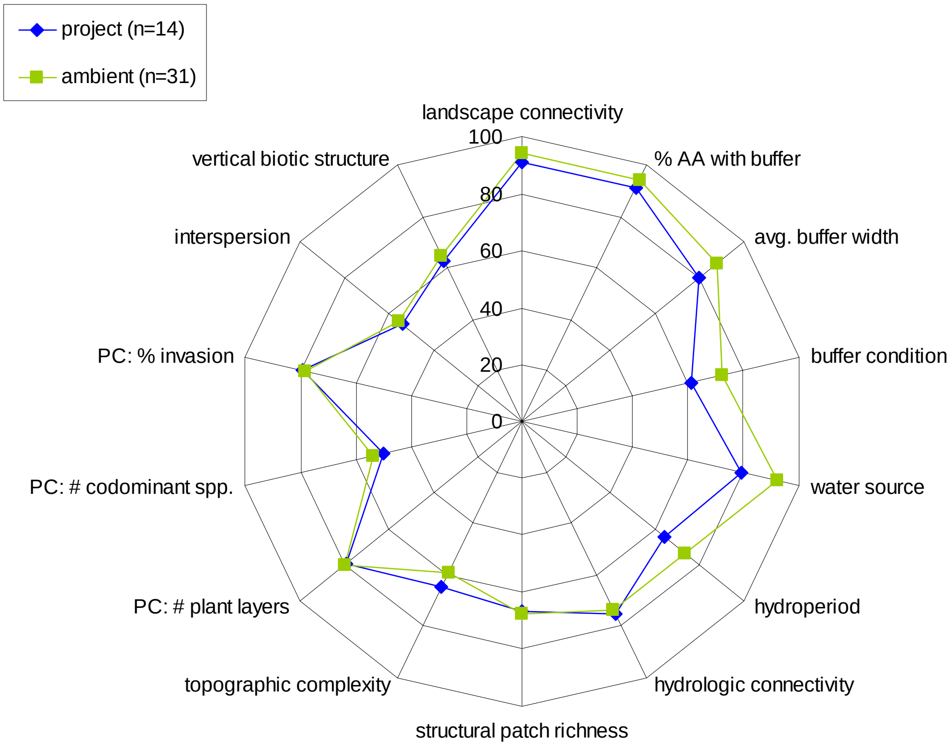


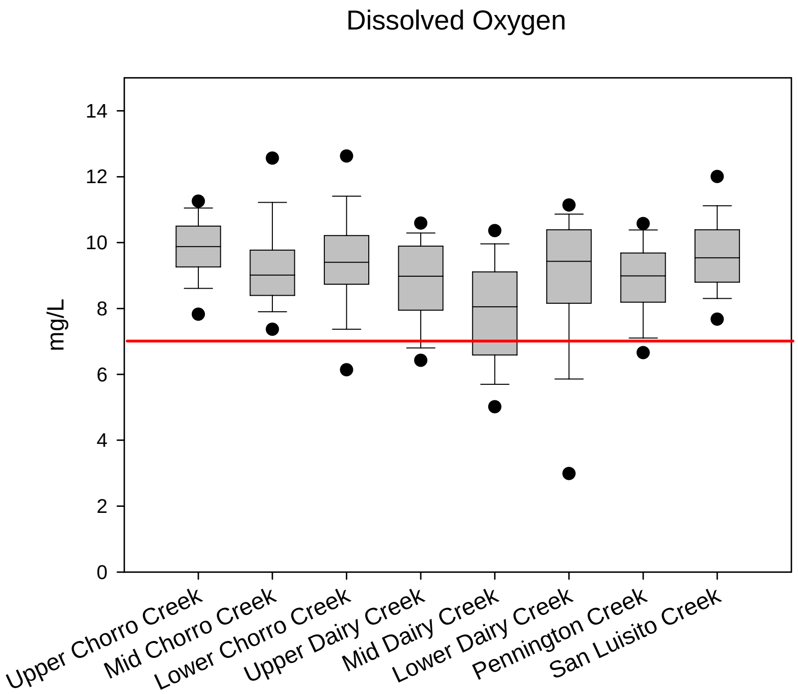
Figure 17. Comparison of the metric scores among project and ambient assessment sites in the Morro bay watershed.

Three of the most common stressors identified at the project sites are also most common at the ambient assessment locations. Restoration project sites had an additional stressor of non-point source discharges, not surprisingly since most restoration projects were near row crop agriculture, grazing cattle, or runoff from parking lots.

Level 3 – Intensive Site Assessment

According to Kitajima (2008), water quality sites that were sampled by the MBVMP from 2002-2007, and were in close proximity to an ambient assessment site, did not have median values that fell below the threshold of 7 mg/L of dissolved oxygen as defined by the Central Coast Basin Plan for protecting fish habitat (Figure 18a). However, many water quality sites did fail the 85% saturation level also set by the Central Coast Basin Plan (Figure 18b). Seventy five percent of the samples at the Mid Dairy Creek site exceeded the 85% saturation threshold. Samples from the upper and lower portions of Dairy Creek exceeded the saturation threshold 42 and 30 percent respectively. Thirty six percent of the samples at Pennington Creek, while 27 percent of the samples from the Lower Chorro Creek site were in exceedance.

a)



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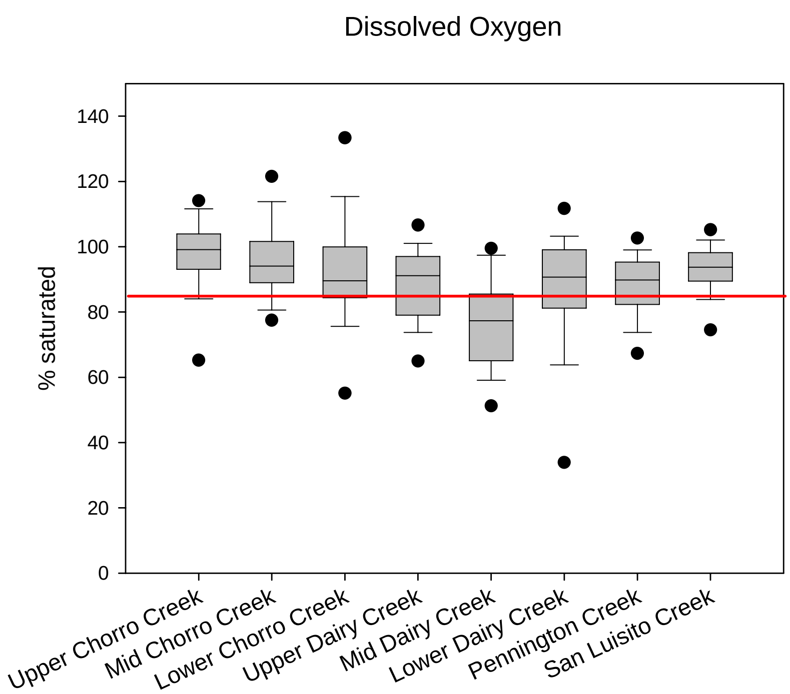


Figure 18. Average recorded a) concentration of dissolved oxygen and b) saturation of dissolved oxygen from 2002-2007 at VMP water quality stations.

The median temperature at the water quality sample sites did not exceeded CCAMP's level of concern temperature of 22 degrees Centigrade (Figure 19a). Additionally, the median turbidity levels at the water quality sites did not exceed the CCAMP informal attention level of 10 NTU (Figure 19b) (Kitajima, 2008).

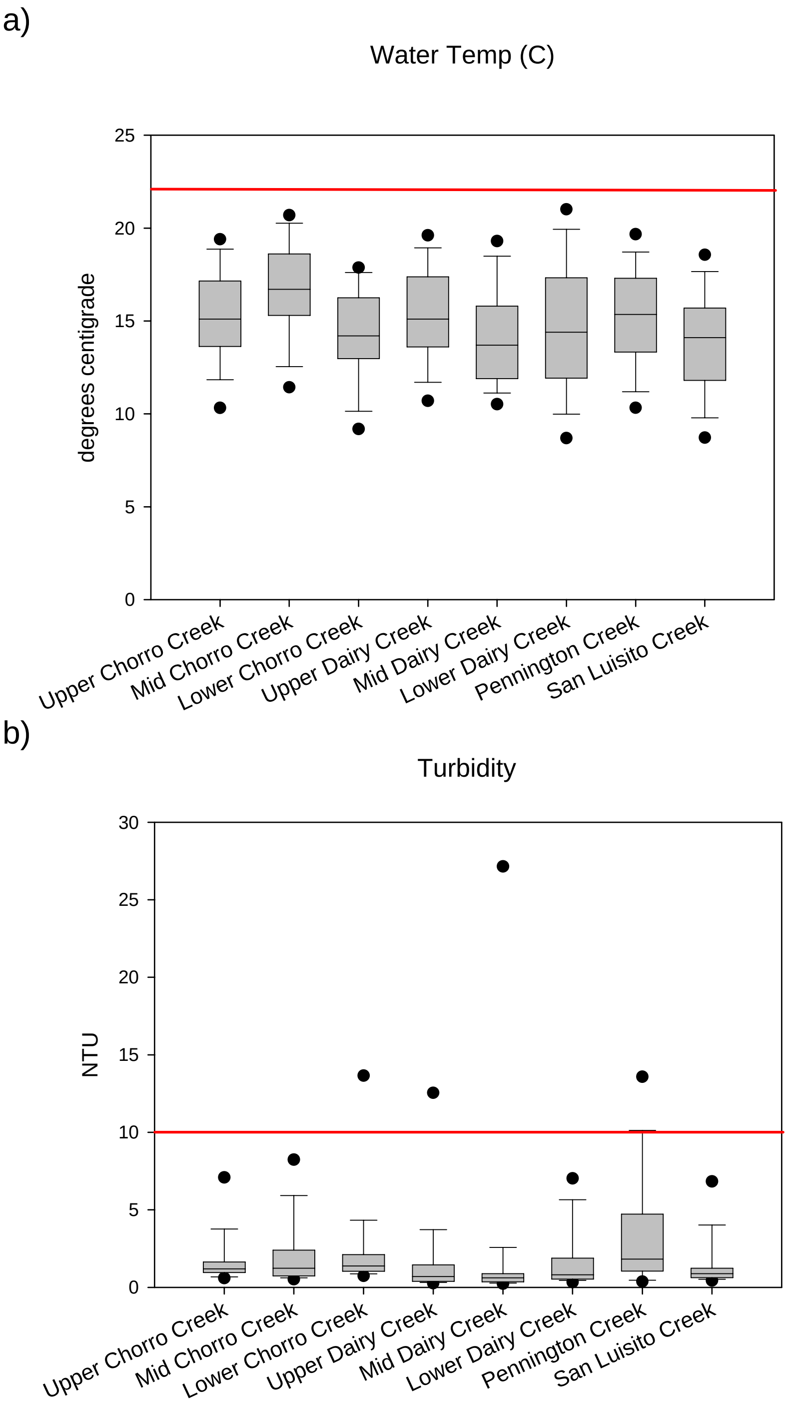
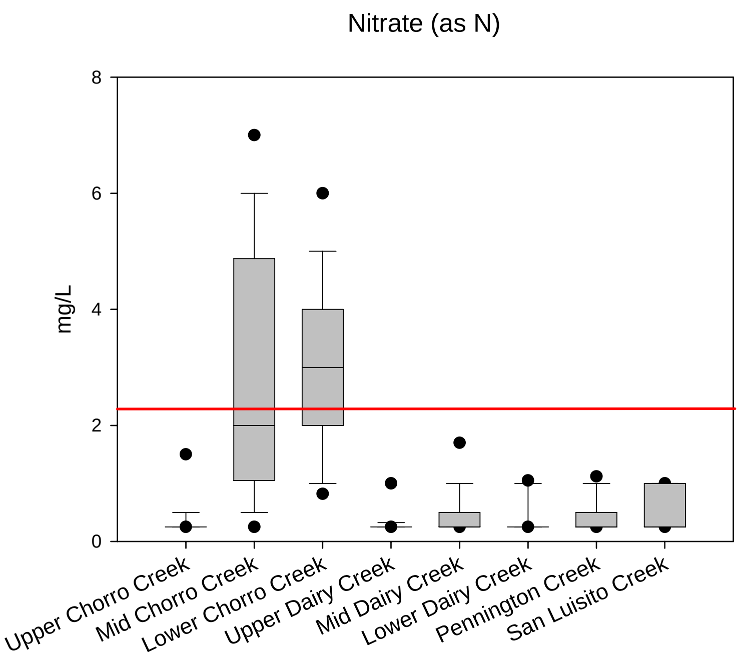


Figure 19. Average recorded a) water temperature and b) turbidity from 2002-2007 at VMP water quality stations.

The median nitrate concentration exceeded CCAMP's level of concern concentration of 2.25 mg/L 46% of the time at mid Chorro Creek and 57% of the time at lower Chorro

Creek (Figure 20a). The median orthophosphate concentrations exceeded CCAMP's informal attention level of 0.37 mg/L at all water quality sites on average 52% of the time (Figure 20b) (Kitajima, 2008).

a)



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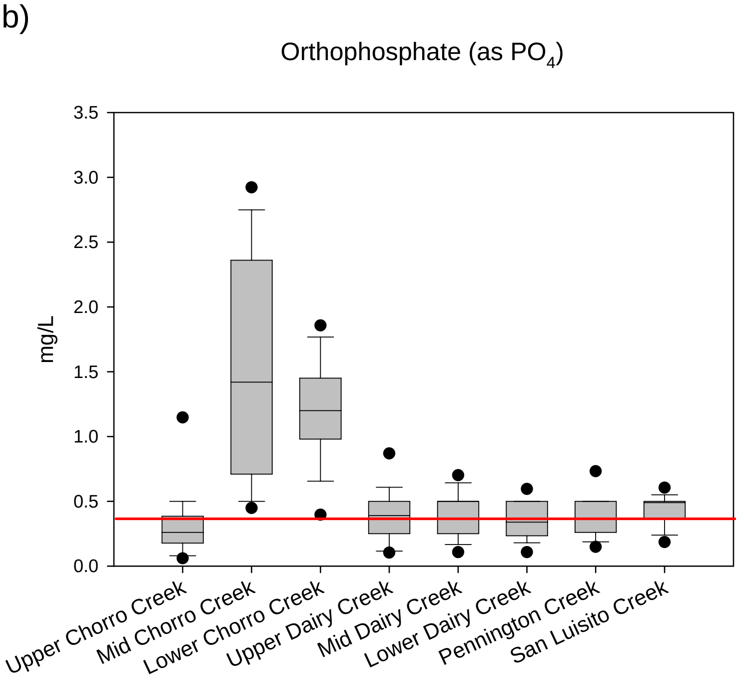

Figure 20. Average recorded a) nitrate concentration and b) phosphate concentration from 2002-2007 at VMP water quality stations.

Results of the comparison of water quality parameters (level 3) to CRAM scores (level 2) revealed little. There was a trend towards an increase in the saturation level of dissolved oxygen and a slight decreasing trend for water temperature and turbidity with an increase in CRAM score, however none of these relationships were statistically significant. Additionally there was a trend towards increasing nutrient concentration (both nitrates and orthophosphates) with an increase in CRAM score, however again these relationships were not significant.

DISCUSSION

The Morro Bay watershed provided an intriguing setting for the application of Level 1-2-3 framework. The wetlands of this watershed had already been intensively mapped by the EPA funded CCWGIS project. The available data provided detailed characterization of the wetland resources within the Morro Bay watershed. The CRAM methodology proved a useful tool for the characterization of wetlands in the watershed. Because of the focus by state and federal agencies (due to the establishment of the Moro Bay National Estuary Program) Morro Bay was an excellent location to integrate the three tiered approach as part of the state wetland monitoring - watershed pilot project.

The Morro Bay watershed was used as a template to demonstrate how various levels of monitoring data can be collected, analyzed, and interpreted to provide a robust, integrative assessment of wetland condition at the watershed scale. A three-tiered monitoring approach that incorporates information on wetland resource extent and distribution (Level-1), ambient condition (Level-2), and intensive site-specific monitoring (Level-3) can be used to prioritize management and restoration activities, identify possible causal relationships of wetland condition (i.e. stressors), and provide context for project and/or site-specific monitoring. This information can further inform management decisions by helping to verify the effectiveness of management approaches, regulatory actions, and public investment in conservation and restoration of wetland resources.

One of the primary objectives of this demonstration was to develop a watershed profile for the Morro Bay Watershed using data on current wetland extent and distribution. Watershed profiles not only characterize the range of wetland and riparian resources at the regional or landscape scale, they can help foster novel ideas on how wetlands function in the landscape and provide innovation in how these resources are managed (Kentula, 2007). For example, mapping wetlands using Cowardin classification provides information on a wetland's vegetative characteristics and water regime. Understanding these processes is an extremely important part of the decision making process for wetland recovery, protection, and land use planning. Wetlands that have been modified and have lost much of their natural functionality are typically good candidates for potential restoration efforts (Dark et al., 2006).

Level 1 assessments are the primary means by which to compile an inventory of wetland and riparian resources via mapping activities at the regional or landscape scale. A primary outcome of this project was to characterize the range of wetland resources in the watershed, and link an ambient condition assessment and water quality data to the population of wetland resources identified.

Hydrology is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. Wetland hydrology is influenced by a number of factors such as precipitation, surface water inflow and outflow, groundwater exchange and evapotranspiration. These processes profoundly affect the biochemistry of wetland soils and biota, so any changes to natural functioning can have a significant effect on the overall wetland system (Mitsch & Gosselink, 1993). The interplay of physical factors is especially pertinent for riverine/flow-through palustrine wetlands and can influence how these systems are managed. Because of the prevalence of these systems in the Morro Bay watershed, conservation efforts that strive to preserve, maintain, or restore natural hydrology, such as improvements in the design of flow-through treatment wetlands and the removal of barriers to streamflow, can contribute signifcantly to improving overall wetland functioning in this watershed.

In addition to the watershed profile, the land use maps provide further context for understanding how stressors at the landscape scale can affect wetland condition in a watershed. The land use maps for the Morro Bay watershed illustrate the land use disparities between the upper (undeveloped) and lower (developed) portions. Different land uses have unique combinations of factors that directly affect watershed hydrology and wetland condition, such as imperviousness and vegetative cover. The upper watershed, where a majority of the riverine wetlands are located, is comprised mainly of forested and non-native grass vegetation types, much of which is either in public lands and/or used as rangeland for cattle. By collecting information about drainage basin land use, it is possible to link wetland characteristics to specific land uses, as well as general changes associated with development.

In the Morro Bay watershed, land use has changed greatly over the last 120 years. Since 1884 the delta has doubled in size, filling a significant area of previously subtidal habitat. This fill is the result of changes in land use practices, such as the introduction of cattle and intensive row crop agriculture which both greatly contributed to erosion in the 1880's (Josselyn et al., 1991) combined with urbanization in the 20^{th} century. This change has not been uniform across the watershed. The two subwatersheds of the region, Chorro and Los Osos, have very different level 1 characteristics. Chorro is composed of public lands (Los Padres National Forest, Camp SLO, California Men's Colony), especially in the mid and upper watershed. Urban and agricultural landuse make up a relatively low proportion of the overall acreage and are focused in the lower watershed, in the valley floor and near the estuary. As a result the stressors acting on this region of the watershed are mainly cattle (grazing, rangeland, etc.) and some agriculture. Conversely, Los Osos is composed mainly of private property. While a lower percentage of the overall wetland acreage is in this sub watershed, more of it is surrounded by agricultural and urban land uses. This leads to an entire different suit of stressors acting on this portion of the watershed. However, due to the relatively high amount of private property in the Los Osos sub watershed, we had extreme difficulty in accessing ambient assessment locations. As a result only two sites were assessed, limiting our ability to draw any conclusions on the effect of landuses and stressors in this section of the Morro Bay watershed.

Coupling current wetland habitat mapping with an understanding of distribution of historical habitat can provide an even greater understanding of how to prioritize recovery efforts in a region or watershed. The mapping of historicalal wetland habitats in the Morro Bay watershed has not yet been completed. However, georeferenced historic aerial imagery available on the central coast wetland website has helped to identify particular wetland areas within the watershed with significant potential for restoration. Slope seep/springs are a wetland type that has been heavily impacted by human activities since historical times. These wetlands are associated with unique hydrologic formations and are relatively rare, making up 3.9% of wetlands within this watershed and often support unique and rare vegetation, making them of special concern for conservation (Dahl & Johnson, 1991). Knowing the location of these wetlands within the watershed is important so that remaining areas can be identified for protection and restoration. The current wetland resource map has defined numerous areas to direct future assessment and restoration efforts to better manage these palustrine systems.

Level 2 assessments of ambient condition provide the context for interpreting habitat data collected at restoration project sites in the watershed. A comparison of cumulative distribution functions for CRAM scores from the 2007 ambient survey sites and the fourteen project sites suggests that restoration project activities are able to achieve condition scores comparable to the best ambient conditions recorded. Cumulatively however, the project condition scores reflect limitations in restoration activities ability to enhance certain aspects of wetland condition, reflected in lower average CRAM metric scores (Figure 21).

Therefore, the CRAM score by itself provides context for the condition of the wetland being assessed. For example, an overall CRAM index score of 72 can be interpreted as median condition compared to all other wetlands within the class being assessed throughout the Morro Bay watershed. Our overall sample frame did not include as vast a range of wetland conditions to those found throughout the state as shown by the SWAMP Perennial Stream Survey CRAM results. Since CRAM score maxima are based on an ideal wetland, it is not surprising to find that high quality wetlands within this semi-arid watershed score lower than wetlands within the state as a whole. However, the low occurrence of sub-optimal wetlands in general within this study is most likely the result of a less degraded overall condition within the watershed as well as limited access to portions of the watershed which potentially have a lower overall condition (Figure 21).

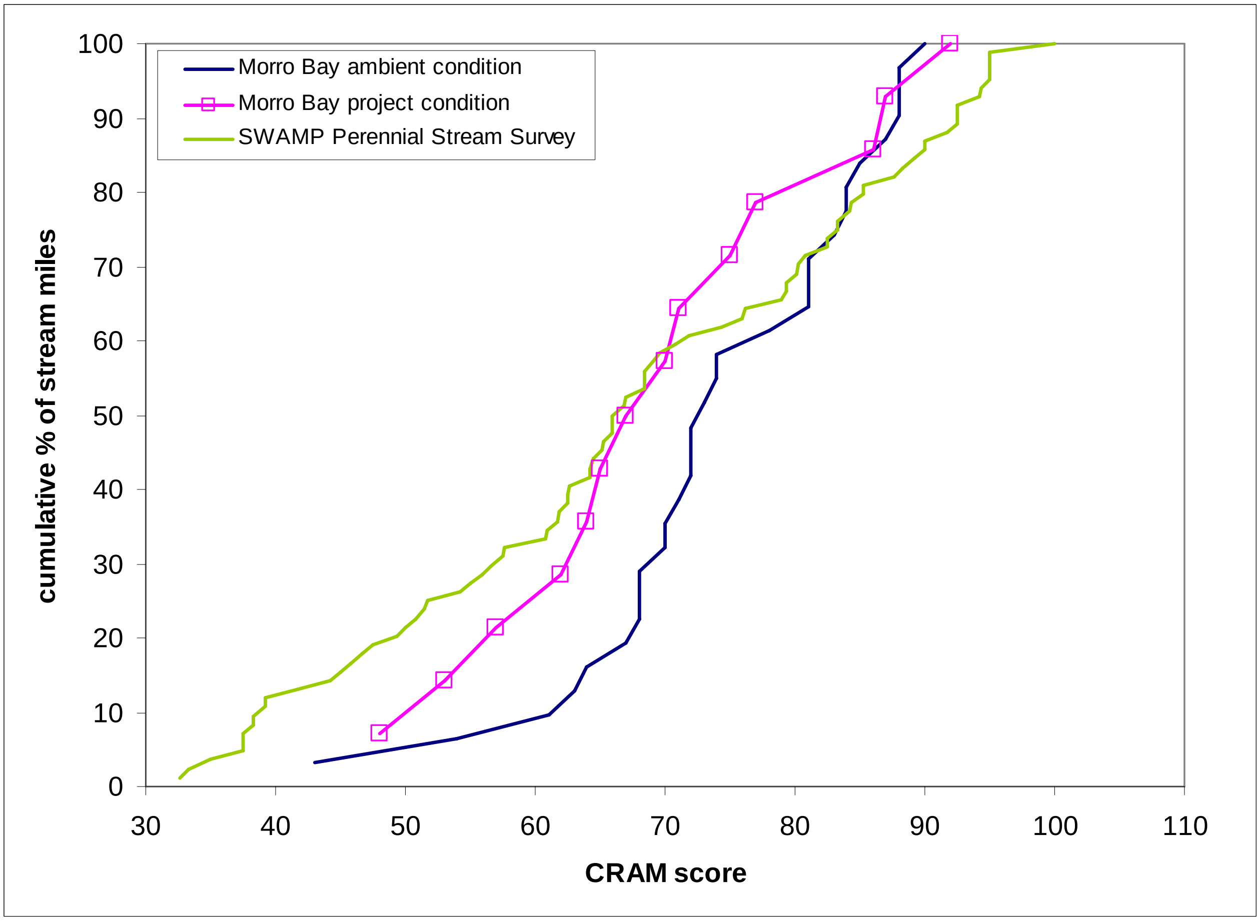

Figure 21. Comparison of the cumulative distribution functions for ambient, project sites, and the SMAMP Perennial Stream Survey of ambient statewide condition assessed with CRAM in the Morro Bay watershed.

Mean attribute and index scores did not vary greatly between the ambient and project locations and are within the margin of error (+/- 10%) so should not be considered significantly different (Table 6). The index score for the ambient and project locations are both in "good" condition as described earlier. The similarity in scores could be because the ambient assessment locations are not well distributed around the Morro Bay watershed due to access issues whereas, the project locations while low in number are well distributed around the watershed, may be in regions that are not highly impacted by human stressors, or it my be that the restoration projects were successful.

Table 6. Comparison of the mean CRAM index and attribute scores between the ambient and project assessments in the Morro Bay watershed

Mean CRAM Index or Attribute Scores	Ambient	Project
Index Score	74	70
Hydrology	29	26
Physical Structure	15	15
Biotic Structure	23	22
Buffer and Landscape Context	21	20

Comparison of the metric scores between restoration project sites and the ambient assessment sites revealed the project assessments scored at or below the ambient assessments with exception of topographic complexity and hydrologic connectivity. The largest metric score difference is seen in water source, followed by buffer condition, hydroperiod, and average buffer width. At the metric scale the ambient assessments seem to be in better condition than the project sites, but overall the CRAM scores are very similar. These data suggest that restoration activities can establish a condition similar to ambient but the individual project condition ranged as widely.
The lower Morro Bay is the most developed portion of the watershed (based on land cover data), but it contains the greatest diversity of Cowardin wetland types. Given this, restoration activities that focus on the lower watershed can play an important role in maintaining wetland resource diversity within the context of the entire watershed. Because the majority of riverine and riparian wetlands are found in canyon areas within the upper Morro Bay watershed, restoration projects that are located in or adjacent to mountain and foothill canyons can contribute substantially to long-term, sustainable management of this wetland habitat class.

The goal of level 2 monitoring is to go beyond the basic level 1 landscape characterization and address management questions on resource condition and anthropogenic stressors at a regional scale using a combination of remote sensing and field based and rapid assessment methods. A second outcome of this effort characterized the range of riverine wetland conditions in the Morro Bay watershed and demonstrated the utility of CRAM for regional ambient assessment, land-use planning and monitoring associated with regulatory programs e.g. (404(d), 401, SWAMP.

Application of Level 2 and 3 monitoring tools at the site project scale provide a context to interpret data obtained from site-specific assessments within the context of the overall ambient condition at the watershed, region, or statewide scale. One of the advantages of using a common rapid assessment tool such as CRAM is the ability to compare scores from a project site of interest to other projects or groups of projects. The combination of these and related tools (e.g. project tracking) can be used to provide assessments of status and trends of wetland and riparian beneficial uses. In addition, it is valuable to understand the ambient condition of the watershed and be able to relate individual projects and wetlands to this distribution of condition scores. Restoration priorities and land management objectives can be greatly enhanced through a greater understanding of the abundance and condition of wetland resources. Incorporation of CRAM into a watershed monitoring program like the MBNMP could be a cost-effective way to provide a more comprehensive assessment of ambient extent and condition of aquatic resources and beneficial uses.

Probabilistic assessments commonly suffer from a lack of access to private property. A large proportion of the Morro Bay watershed is privately owned. Very few landowners granted access to their property. This limitation of ambient assessment projects can lead to omissions in the distribution of assessment location across the watershed and may hinder the true characterization of the watershed. Greater effort could have been placed in the landowner contacts and building trust with the landowner.

CONCLUSION

The Morro Bay watershed was selected to demonstrate how the level 1-2-3 monitoring framework could be applied to assess wetland condition. Results suggest that the watershed as a system is in good condition with only 10% of sites being characterized as suboptimal while 39% of sites statewide were found to be suboptimal. The percentage of excellent condition riverine wetlands were similar to state averages, sites that have been impacted by adjacent land uses, are less degraded than those compared statewide. This is represented by the significant percentage of sites in good condition. Highly impacted sites may be rare within this watershed (<10%) because of the limited urban encroachment pressure within the sample area.

The results of these studies illustrate the merits of using various levels of data (i.e. wetland resource extent/distribution, ecological condition, and intensive site-specific monitoring) to provide a robust assessment of overall watershed condition. In addition, this project provided the means to show how information generated from level 1 landscape scale and level 2 rapid assessments can be used to interpret and/or supplement more intensive, level 3 data. A monitoring program based on the level 1-2-3 assessment framework can be used to guide wetland restoration, provide data on regional wetland condition, and verify the effectiveness of management approaches and/or regulatory actions. Incorporation of this overall framework into agency wetland monitoring programs provides a valuable opportunity to evaluate the effectiveness of public investment in conservation and restoration of these resources.

More specifically, this study reveals the need in Morro Bay for greater linkage between Level 2 and Level 3 data. Morro Bay National Estuary Project is currently conducting level 3 monitoring through its Volunteer Monitoring Program. If a new program were developed to simultaneously collect level 2 and level 3 data more information about the watershed condition could be extracted. More could be understood about the problems which the Morro Bay watershed faces while enabling the formulation for management. In order to do this multiple agencies would need to collaborate and develop a plan together. Using the adaptive management approach could greatly improve the effectiveness and streamline the process of the multi-agency collaboration.

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APENDICIES

Appendix 1. Overview of restoration project sites assessed with CRAM in the Morro Bay watershed.

1) Chumash Creek BMP Improvement Project
Chumash Creek is one of the smaller tributaries to Chorro Creek, located between Walters Creek and San Luisito Creek. The goal of this project was to evaluate the effectiveness of BMP's on improving water quality and habitat value. The BMP's were installed over the course of three years and were evaluated for five years after the installation. Beginning in 1995 the riparian corridor was fenced off, the size of cattle grazing pastures were decreased and water was redistributed to irrigate the pastures equally, channel stabilization and revegetation occurred, farm road improvements were made, and an in-stream stock pond was removed. These actions were expected to result in improved water quality, riparian habitat, rangeland productivity, and reduced sediment load discharge into the lower Morro Bay watershed and estuary.

2) Walter's Creek Riparian Restoration Project Phase II
The project area is just south of the San Luis Obispo Wildlife Area on property purchased by California Polytechnic State University in the early 1980's and just north of California Department of Fish and Game (CDFG) property. Prior to the 1930's all of the riparian vegetation was removed along this section of Walter's Creek. Cal Poly has managed this area as open rangeland, allowing the cattle direct access to the creek for their water source. This project is part of a long-term strategy to improve conditions for steelhead in the Morro bay watershed through habitat improvement. The actions taken during Phase II were as follows; removal of eroding culverts, filling of incised portions of channel to widen the floodplain, creation of 1200 linear ft of new channel with greater sinuosity and less slope to decrease water velocity, creation of a functioning floodplain, revegetation and stabilization of the main channel, cattle fencing to protect the riparian zone, and long term native wetland and riparian enhancement.

3) Los Osos Creek- Morrissey property
This restoration project was commissioned by private landowner Marla Morrissey to Meredith Hardy with the California Conservation Corps after a winter event took out an entire slope and lower riparian bank. This stretch of the Los Osos Creek is in the mid watershed after a sharp turn in the river. The stream is confined and entrenched, with severely eroded banks at the project site and downstream. Rock structures, and willow walls, were constructed to stabilize the slope. However, the following winter significant rains lead to high water volume which destroyed most of the willow walls.

4) Upper Los Osos Creek- Swift Property
This project is located on private property in the upper watershed of Los Osos Creek. The landowner in conjunction with Morro Bay National Estuary Program implemented a restoration project to enhance the habitat. In the channel boulders were placed, pools were created, flow impediments were modified, the stream bank was re-sloped, rock

weirs and root wads were installed, riparian and upland restoration and bank stabilization occurred.

5) Pennington Creek
This project was done on Pennington Creek at Cuesta College, just west of Highway 1. The purpose of this restoration project was to decrease erosion and stream sedimentation, increase stream bank stabilization, and to provide improved habitat for steelhead trout in Pennington Creek. This was accomplished by placing boulders, deflectors, hardwood planting, and willow planting

6) Warden Creek
The purpose of this project is to restore the culvert and creek area to its previous condition. The creek was damaged when unauthorized work occurred by county maintenance crews. Subsequent clearing and snag creation in addition to some riparian planting was done.

7) Chorro Creek-Flats
Chorro Flats is located in the lower watershed of Chorro Creek below all of the main tributaries. It is surrounded by agriculture and is adjacent to Highway 1. The property was acquired by the Coastal San Luis Resources Conservation District (RCD). The RCD efforts partially funded by a Clean Water Act Section 319 grant to monitor the effectiveness of the sediment floodplain proved to be successful. The Chorro Flats Enhancement Project was implemented to reduce sediment loads to Morro Bay by allowing Chorro Creek to overflow onto its original floodplain. The project has restored and enhanced 83 acres of wetland and wildlife habitat.

8) Chorro Creek-Below Dam (Cattle Exclusion Project)
Upper Chorro Creek consists of three main stems in the upper watershed which converge and have been damned to create Chorro Creek reservoir. A total cattle exclusion area on the Camp San Luis Military Reservation was created. Fencing was installed along the riparian corridor of upper Chorro Creek in 1994 starting just below Chorro Creek Dam and ending just above the California Men's Colony. The goals of this project were to eliminate access to the creek by cattle thus increasing water quality. Water sampling stations were set up above and below the project sites to monitor the water quality as it flowed through the project site. Water quality has significantly improved since the fence was installed.

9) Chorro Creek-Chromium Mine
Due to the damage done by the Chromium Mining in the west fork of the upper Chorro Creek watershed, serious continual erosion occurred each year. Runoff from the steep canyon slopes that were conveying water to the channel needed to be controlled, so pipes were placed on the hill side to help control the directional flow of water. Jute matting and plastic netting filled with plants were placed on the steep slopes to protect from further erosion into the channel. The channel banks were lined with many tons of rock to dissipated the energy of water and stabilize the banks to prevent the entire channel from washing away. The scars from this mining operation are highly visible from aerials and will take many more restoration efforts to mitigate for this damage.

10) Dairy Creek

Dairy Creek is a tributary to Chorro Creek. The headwaters originate in the Los Padres National Forest, flow through El Chorro Regional Park, and crosses Highway 1 to meet the main stem of Chorro Creek. This is the site of a cattle exclusion project. The land was grazed for many years without creek corridor protection, and in many areas the riparian vegetation was severely damaged. The USDA Natural Resources Conservation Service partnered with San Luis Obispo County Parks Department and the Guidetti family, historical owners of the Dairy Creek Ranch, to create a proposal. The project focused on fencing and revegetation of a mile-long riparian corridor which flows through the park. Improvements to the lower section of creek were completed during the summer of 1994 and the remaining upstream portion of creek was fenced during the summer of 1995.

11) Chorro Creek-Canet Rd.

This project site is located along the Chorro Creek, which flows west into Morro Bay. The project area is located on a private drive off of Canet Road. The purpose of this project was to protect the toe of the eroding bank after a serious bank slide. The road located along the eroded upper slope was moved away from the edge. The vertical slope was terraced to help re-vegetate and stabilize the bank slump. Rock and root wads were placed on the toe of the slope to protect the bank from any further erosion as the vegetation grows.

12) Chorro Creek-Camp SLO

This project is located just below the California Men's Colony. The project ended up in our database but no information could be found. The actual date this project was completed is unknown. No files were found only evidence on the creek itself was found. Downstream of the bridge on Santa Cruz Road, the creek takes a sharp west turn. Highway 1 is adjacent to this turn. This seemed to be the area of concern. In a high flow event the river could wipe out the channel and flood the freeway. A crib wall was installed and large boulders were placed at this high energy location. Downstream of the structure the steep slopes were severely degraded. There was evidence of small scale riparian planting. There was evidence of a dam downstream of the crib wall instillation, however only remnants could be seen. At some point the dam was destroyed and we do not know if this was part of the restoration actions.

13) Los Osos Creek-Wetland Reserve

This is phase II of the Morro Bay Watershed Enhancement Plan. This 144 acre site is located at the confluence of Los Osos and Warden Creeks just upstream of the Morro Bay estuary. The agricultural land is owned by George Martines. The USDA Natural Resources Conservation Service and the Coastal San Luis Resource Conservation District (CSLRCD) have purchased permanent wetland reserve easements on the property. The State Coastal Conservancy provided funding for the CSLRCD easement. The easements were acquired and 111 acres of flood plain and riparian habitat was to serve as a sediment deposition area, trapping sediment before entering Morro Bay. Thirty-three acres are permanently protected in an agricultural easement. One key component of the plan is to provide a sediment trap on Los Osos Creek near its confluence with Morro Bay. Historically the site was a freshwater wetland and riparian forest. In the 1900's the site was converted to agricultural use. The creek bed was altered and levees were constructed for flood control. It was farmed continuously until 1995, but has since been allowed to revert back to wetland habitat. The floods of 1995 did a great service by rupturing the levees and spreading over the area millions of willow cuttings. Today, the site is functioning as a sediment trap and is outstanding wildlife habitat.

14) Chorro Creek-Morro Bay SP

The project site is located downstream of the Chorro Flats Restoration Project in the stretch of creek above and below Twin Bridges. In 2002 the goal was to eradicate the Cape Ivy that had invaded the riparian corridor. Using manual removal and herbicides the ivy was removed. A bio-control agent was then planned to be used for continued success of the cape ivy removal. The project relied on the projected availability of the bio-control agent to be successful but it did not arrive. The project lapsed and the cape ivy grew back resulting in the project being unsuccessful.