STATE OF CALIFORNIA

NATIONAL ESTUARY PROGRAM

THE NOMINATION OF MORRO BAY

ADDENDUM

AUGUST 1992

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

STATE OF CALIFORNIA

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AND THE
STATE WATER RESOURCES CONTROL BOARD

NATIONAL ESTUARY PROGRAM

THE NOMINATION OF MORRO BAY

ADDENDUM

W. Don Maughan
Chairman
State Water Resources Control Board
901 P Street
Sacramento, CA 95814

James M. Strock
Secretary for Environmental Protection
California Environmental Protection Agency
555 Capitol Mall, Suite 235
Sacramento, CA 95814

California Environmental Protection Agency

Air Resources Board • Department of Pesticide Regulation • Department of Toxic Substances Control • Integrated Waste Management Board
Office of Environmental Health Hazard Assessment • State Water Resources Control Board • Regional Water Quality Control Boards

Wilson
Governor

James M. Strock
Secretary for Environmental Protection

AUG 17 1992

Honorable William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Attention: Ms. Marian Mlay
Oceans and Coastal Protection Division (WH-556F)

Dear Mr. Reilly:

We have received the August 3, 1992 letter from Robert H. Wayland, III, seeking additional information on Governor Wilson's nomination of Morro Bay for inclusion in the National Estuary Program (NEP). To respond to the questions posed in Mr. Wayland's letter, we have prepared an addendum to the original application, which we have enclosed with this letter.

To facilitate your review of the addendum, we have included each of Mr. Wayland's questions, along with our responses. We have also included supplementary maps, bibliographies, etc., to fully answer the various queries.

We appreciate the opportunity to provide you with the additional information you need to consider the Morro Bay application. We believe that this additional information should fully respond to the questions posed, and provides strong justification for the inclusion of Morro Bay in the NEP. The State of California still strongly supports the proposal, which we trust will be successful.

If you need any additional information on this nomination, please feel free to contact Craig J. Wilson, Chief of the Bays and Estuaries Unit, State Water Resources Control Board, at (916) 657-1108, or Steve Eabry, Coordinator, Morro Bay Task Force, at (805) 549-5723.

Sincerely,

James M. Strock
Secretary for Environmental Protection

W. Don Maughan
Chairman, State Water Resources Control Board

Enclosure

555 Capitol Mall, Suite 235 • Sacramento, California 95814 • 916/445-3846 • Fax: (916) 445-6401

THE NOMINATION OF MORRO BAY
ADDENDUM

TABLE OF CONTENTS

NATIONAL ESTUARY PROGRAM

THE NOMINATION OF MORRO BAY
ADDENDUM

INTRODUCTION

In accordance with Section 320(a)(1) of the Clean Water Act, the State of California submitted the nomination of Morro Bay, San Luis Obispo County, California to the U.S. Environmental Protection Agency (EPA) on May 30, 1991 for inclusion in the National Estuary Program (NEP). The nomination package was unsolicited at that time. However, on February 20, 1992, EPA had a call for submissions to the NEP, and the Morro Bay nomination package was accepted for consideration during the open nomination period.

On August 3, 1992, the State of California received a letter from Robert H. Wayland III, Director of the Office of Wetlands, Oceans and Watersheds, EPA. The letter requested that the State of California supplement the original nomination package by addressing issues raised during an initial review of the nomination.

The responses to the issues identified by EPA are contained in this addendum to the original Morro Bay nomination package.

RESPONSES TO EPA QUESTIONS

The State of California responses to the questions raised in the August 3, 1992 letter from EPA are listed in the same order as in the EPA letter. The questions posed by EPA preceed our responses.

National Significance

1. Question

   The nomination does not clearly demonstrate how the Morro Bay estuarine system would expand the types of problems covered by existing NEPs, and therefore of national significance.

   Response

   Morro Bay is an estuary of national significance because it is relatively unpolluted, little impacted by humans, and provides a demonstration project for the NEP to implement pollution prevention measures. Morro Bay is threatened by toxics (chromium and nickel from mining) and pathogens (bacteria from runoff and septic systems). A demonstrated problem is sedimentation of bay wetlands which is slowly destroying remaining wetlands.

   The Morro Bay nomination provides a unique opportunity for implementing pollution prevention measures to lessen the threats to the Bay's ecosystem rather than expanding on the types of problems covered by bays and estuaries already in the NEP. The point sources of pollution in and around Morro Bay have been controlled to a very large degree. The

challenge now is for the water quality protection activities to anticipate and avoid the impacts of increasing land use and other attendant problems.

Most of the existing NEP projects are focussed on solving and remediating years and possibly decades of pollutant insults. The Morro Bay project will focus on avoiding impacts of land use, public land management, agriculture, residential development, and other nonpoint source concerns by implementing strategies to completely avoid these problems before they cause serious impacts to the estuary.

Morro Bay will serve as an example of a nonindustrialized, urban area that prevents pollution before it enters a precious coastal resource.

The pollution prevention approach is one of the cornerstones of the State of California environmental protection goals established by Governor Pete Wilson. His third goal (among six) is:

> ". . . [The State of California] must act to prevent the creation of pollution in the first instance--it is not sufficient, from an environmental or economic standpoint, to focus solely on pollution as it exits the pipe or stack." (P. 1, Governor's Reorganization Plan, Number One, 1991, Creating the California Environmental Protection Agency.)

EPA has also recognized the importance of implementing pollution prevention activities through (1) development of guides to pollution prevention (for industry and building trades), (2) incorporation of the concept in its draft strategy for sediment management, (3) the activities of EPA's Office of Prevention, Pesticides and Toxic Substances, and (4) the NOAA/EPA/State implementation of the CZMA amendments.

Morro Bay can be effectively protected by implementing pollution prevention measures on a watershed scale. Morro Bay and other relatively clean bays and estuaries (including the Monterey Bay Sanctuary established just north of Morro Bay) cannot be protected unless land use practices are linked to water quality protection. We are confident that Morro Bay can serve as a model for the preservation of our threatened coastal resources.

Morro Bay's management plan will be a model for all of the small relatively unspoiled estuaries across the nation. Morro Bay offers the National Estuary Program important factors not being addressed at this time, and is, therefore, of national significance.

2. Question

Given the importance of the nomination assigned to wetlands in Morro Bay, the nomination would benefit from a more detailed description of the quantity and diversity of wetlands, specific threats to wetlands, and a discussion of how the management conference would provide ecosystem level protection for wetlands.

Response

Morro Bay wetlands have been mapped and described in a number of studies, including the U.S. Fish and Wildlife Services Wetland Inventory. The various categories are shown on the watershed map (Appendix 1A).

Wetland habitats found in Morro Bay include Subtidal and Intertidal Eelgrass (730 acres), Coastal Salt Marsh (500 acres), Coastal Brackish Marsh (80 acres), Coastal Freshwater Marsh (35 acres), and Riparian Woodland (120 acres). Additional riparian woodland habitat is found along both Chorro and Los Osos Creeks and their tributaries. These habitats support a number of sensitive species, including the Black Rail and Salt Marsh Bird's Beak. Morro Bay supports the largest and most unspoiled wetland habitat in central and southern California.

Probably the most serious threat to these wetlands is the rising elevation of the creek deltas as a result of increased sedimentation. The management conference would develop a statement of desired ecosystem characteristics at, say, the end of 5 years, 10 years, and 50 years. The steps to be taken to reach such goals would be outlined. All interested parties will have input in development and implementation of the management plan, and all agencies would use the plan to take the necessary steps. The considerable community support through groups such as the Friends of the Estuary at Morro Bay will be used to urge the agencies to take action. Encroaching development, particularly in riparian forest areas, is impacting wetland acreage in some areas, particularly the back bay. Currently high ground water levels from septic systems in Los Osos and Baywood Park may help maintain freshwater wetlands at the edge of the back bay. If sewage treatment is implemented in this area, it must be done in a way which ensures that this freshwater marsh habitat is maintained. Hoary cress, an introduced plant species, is invading brackish wetlands at the mouth of Chorro Creek and is reducing its biodiversity. The progressive effect of sedimentation in filling the Bay is documented in the research studies funded by the California Coastal Conservancy.

The Morro Bay wetlands are a significant natural resource in the State of California because nearly 91 percent of California's wetlands have been destroyed.

Geographic Scope of the Estuary

1. Question

The maps that are included in the nomination are very difficult to read and, in some cases, illegible. A clear, detailed map showing the locations and types of land uses would be a helpful supplement. The map should include descriptions of parks, types of agriculture, and residential and commercial property zones.

Response

Please refer to Appendix 1, maps of the watershed, which update the original filing.

2. Question

Apparently the study area does not include the Morro Bay-Cayucos sewage treatment plant. Given the major impact the plant's discharges have on Bay water quality, excluding the plant from the study area calls into question the ability of a Morro Bay Management Conference to succeed. The nomination would benefit from a discussion of this major issue.

Response

Effluent from the Morro Bay-Cayucos sewage treatment plant is discharged into Estero Bay and does not enter Morro Bay directly. It discharges north of the mouth of Morro Bay from a multiport diffuser one-half mile from shore and approximately one mile from the mouth of the estuary. This effluent has been chlorinated since 1986, as ordered by EPA. Recent monitoring of coliform bacterial levels indicate that concentrations within the Zone of Initial Dilution remain below 17 per 100 ml (MPN). The Section 301(h) modified NPDES permit permitting discharge of primary treated effluent through this outfall can only be renewed as long as continual monitoring of the discharge does not identify significant water quality problems resulting from the discharge. To date, such problems have not been identified, and the plant continues to operate under the waiver. A California Regional Water Quality Control Board (Regional Water Board) bacterial study of Morro Bay (FY 1986-87) was conducted to locate the source of coliform bacteria in resident shellfish. Several sources of bacteria were identified. However, the study did not identify significant water quality problems at the mouth of the Bay. In fact this area was routinely the cleanest water in the Bay. The effluent could periodically enter the mouth of Morro Bay as a result of ocean currents and tidal action, and if Morro Bay is accepted into the NEP further study of the impacts of this plant may be warranted as part of the program. Potential indirect effects of this treatment plant discharge and other facilities in Estero Bay (marine terminals and power plants) will be considered in the planning process as appropriate. We believe that strict adherence to watershed drainage territory in the NEP area is a simple concept that is more desirable by the general public, especially in resisting pressures to use the program for consideration of issues unrelated to an estuarine management program.

3. Question

While there is mention of Morro Bay, Baywood Park, Los Osos, and Cuesta-by-the-Sea, the nomination does not give an adequate description of developed and incorporated areas (i.e., cities and towns) in the study area. EPA would be in a better position to evaluate the development pressures impacting the estuary if the nomination provided information on the population, growth rates, and legal standing (i.e., incorporated vs. unincorporated) of all communities in the study area.

Response

The human population in the watershed is in excess of 35,000 people, resulting in a watershed population density (400+/mi^2) much greater than many other functioning estuaries. There is some variation because of the changing populations (and resident staff) in Camp San Luis Obispo and the California Men's Colony. The students, faculty, and staff at Cuesta College is also very large at most times. The government complex of these combined facilities and the adjacent County jail and offices is, in fact, an urban development in excess of 10,000 people that greatly impacts Chorro Creek and the estuary.

The 35,000 people in the watershed is almost triple the population in 1960, and development pressures are intense in both the Chorro and Los Osos Valleys in addition to Los Osos itself.

Boundaries of incorporated areas (only the City of Morro Bay) and the urban boundary lines of Los Osos (Baywood Park, Los Osos, and Cuesta-by-the-Sea) are shown on the attached watershed map (Appendix 1B).

The Urbanized Areas

The population of the City of Morro Bay is now 10,000. Only a portion of Morro Bay City is in the watershed. Since the development potential of Morro Bay in the watershed is limited, the future impact of this population should not increase.

In Los Osos the population is now 15,960. The population has increased threefold from 1970 when the population was 5100, to the present. The current General Plan has a target population of 28,000. The management plan should address the impact of a doubling of the population in Los Osos. The Los Osos General Plan will be reviewed and updated in the next two years and should incorporate recommendations developed in the management conference.

The County of San Luis Obispo has grown rapidly in the last few years. It currently has a growth rate cap for residential development of 2.3 percent per year. Within the watershed, however, pressures to develop visitor-serving facilities constitute potentially the most serious future impact to the estuary. At the present time, three golf courses are proposed along with conference and hotel facilities within the Chorro Creek basin. Other future projects are likely.

Again, if estuarine management and pollution prevention measures can be incorporated into the General Plan update, potential impacts of these projects on the estuary can be adequately addressed within a Comprehensive Planning framework. Other populations within the watershed include: Cuesta College (population 7,900; growth rate 3 percent), California Mens Colony (population 6,000), and Camp San Luis (population 1,000).

Environmental Problems and the Cause-and-Effect Relationships

1. Question

The nomination discusses the cause-and-effect relationships of problems theoretically or generically, but does not convincingly demonstrate a connection. It is vital that an awareness of specific problems be discussed in detail in order for EPA to understand and evaluate the condition of the estuary, as well as the state of knowledge concerning these problems.

Response

At least three water quality problems have been identified which threaten the health of the estuary.

A. Sedimentation has been identified as an obvious problem in several studies on the watershed. At current sedimentation rates, the Bay will be filled within approximately 300 years rather than the several thousand years under natural conditions. The U.S. Soil Conservation Service has completed an erosion and sediment study of the watershed (1989) which estimates the amount of sediment generated by various land use practices in the watershed. Other studies, conducted in the Bay itself, using historic and current aerial photographs and other information sources, have documented steadily increasing delta elevations, increasing acreage of more upland habitat types, and encroaching introduced plant species, all indicating changes in the estuary resulting from siltation.

B. Bacteria and associated pathogens have been identified as a problem in the estuary in several studies. Monthly State Department of Health Services studies have identified occasional contamination of shellfish in the Bay, forcing closures of commercial oyster operations at times. A bacterial study of the Bay conducted by the Regional Water Board in 1987 identified high fecal coliform levels in portions of the back bay where septic systems are potential sources, along the Embarcadero in Morro Bay, near the marina in Morro Bay State Park, and in Chorro Creek itself. Several point sources were identified as a result of this study, but much of the contamination appeared to result from a variety of non-point sources. The Regional Water Board is currently monitoring bacteria levels in the back bay and in Chorro Creek.

C. Metals (chromium and nickel)--Abandoned mines in the Chorro Creek watershed have contributed relatively high levels of nickel and chromium to the watershed. A current study being conducted by the Regional Water Board has identified levels exceeding Basin Plan standards in several sites below the mines. It is not known to what extent these metals have accumulated in the bottom sediments of Morro Bay itself.

D. Water Diversion--Water diversion on both Chorro and Los Osos Creeks degrades habitat both in the creek and the estuary. Over-diversion has contributed to the reduction of the steelhead trout fishery, and may have eliminated the tidewater goby from its habitat in the lower creeks. The acreage of irrigated agricultural land in the watershed has increased considerably in the past decade. Land that at one time was used for dry land farming is now planted with water-intensive crops such as snow peas and is frequently farmed year-round. Municipal diversion of Chorro Creek is resulting in impacts in surface flow, and in dry periods, including many summers, the creek does not flow to the estuary. This creek is so heavily diverted that a proposed effluent reclamation project by the California Mens Colony is being protected, as many fear that without the effluent the creek will be dewatered much of the time. The Los Osos creek watershed has been declared "fully diverted" by the State Water Board, indicating that they do not believe that any additional water is available on that creek for further diversion. Availability of fresh water on the watershed is definitely an issue in need of further study.

E. Other concerns include the loss of steelhead fisheries in both Los Osos and Chorro Creeks, destruction of riparian habitats, water quantity, and loss of sensitive habitats.

2. Question

With the possible exception of sedimentation studies, the nomination does not describe conclusions of existing studies of the estuary and therefore gives the impression that very little is actually known about problems in the estuary.

Response

It is true that little is actually known about problems in the estuary. The need for research is being addressed (see especially Appendix 2) but much more will be needed. This lack of knowledge will be addressed with our participation in the NEP. The proposed budget for the management conference takes into account the need for further research. However, the need for research does not mean that the management conference will not take action in the short term. Once developed, pollution prevention measures can be implemented very quickly.

Question 1 above addresses existing studies regarding sedimentation, bacteria, and heavy metals. Studies in other categories include:

A. **Hoary Cress**--A study for the State Department of Parks and Recreation has been conducted on the invasion of hoary cress in Chorro Creek's delta area. As brackish water wetlands are disturbed and filled by increasing sedimentation from the upper watershed, the spread of this invasive, introduced-plant species is exacerbated. A second study addresses potential control programs for the plant.

B. **Tidewater Goby**--Recent surveys for this sensitive species have not located it in the lower creek mouths since 1986. Siltation of brackish water areas and pumping of freshwater have been identified as problems resulting in degradation of its specialized habitat.

3. Question

The relationship between the health of the estuary and the local and regional economy is not demonstrated. For example, a discussion of the history and decline of Morro Bay's once-significant oyster population, the clear role of pathogens from the Morro Bay-Cayucos sewage treatment plant's Section 301(h) discharge in creating this decline, and the economic impact on the region would be helpful.

Response

The health of the local and regional economies are tied directly to the health of Morro Bay. Morro Bay is known for its scenic beauty, diverse animal life, commercial fishing industry, sport fishing and other forms of aquatic recreation. We have not found a decrease in oyster farming acreage from peak levels in recent years to the current lower level is

caused by anything but marketing limitations. At times, high bacterial levels in the Bay have forced closure of shellfish fisheries. Such closures not only impact recreation or commercial use of the area at times, but also impact public perception of the Bay as a pristine, clean, safe environment that is desirable to visit. In addition, at least 100 acres of once-productive oyster beds are now unusable because of increased sedimentation in the Chorro Delta. Local commercial fisheries depend in part upon the nursery values of the estuary for production of fish. Impacts to the estuary which may impact juvenile fish production include filling of open water habitat and dredging activities, both directly related to sedimentation.

4. Question

The nomination describes the NEP as a land preservation program, but the NEP is essentially a water quality protection and planning program. The nomination would benefit by clarifying the significant water quality problems in Morro Bay that the NEP can focus on, or alternatively show that there are no major problems and Morro Bay is a pristine estuary that needs to be protected.

Response

The issues and plans in the Morro Bay watershed are not land preservation, rather they are primarily watershed water quality planning through improved land use planning. As identified earlier in the response to questions, significant water quality problems include erosion and sedimentation, bacteria and associated pathogens, nickel and chromium levels. The focus of management planning is being placed on improvement in these existing problem areas, as well as planning for long-term management of the watershed in a way which forestalls additional water quality problems in the future. Other than siltation, the Bay itself has relatively few threats and falls in the program category of preserving a little-polluted viable ecosystem.

Institutional Arrangements

1. Question

The nomination could be significantly improved by including a thorough description of the role of existing Federal agencies and programs which are responsible for protecting the estuary (e.g., NPDES program), including successes, deficiencies, and implementation of these programs. For example, discuss in detail Section 319 monitoring projects, Section 301(h) discharge permit plans, and Section 404 dredge and fill activities to name a few.

Response

A management conference is necessary to provide the framework for successful management and maximum benefit of all programs. Existing Federal programs which function to protect the estuary include:

Clean Water Act (CWA) Section 319(h)--provides funding ($163,000) for Soil Conservation Service (SCS) technical staff implementing the Morro Bay Watershed Enhancement Plan. This program is currently funded through 1994. Local landowners work with SCS to devise and implement management plans for their land to reduce erosion problems in the watershed. A number of landowners are already participating in the program.

CWA Section 319(h)--The State Water Board and EPA have also provided funding ($100,000/year) for a ten-year "paired watershed" study. This study will monitor changes in sedimentation and water quality on a watershed treated with best management practices, and compare it to a similar watershed where such practices are not in effect. This study is expected to begin data collection this winter.

CWA Section 205(j)--Tfhe State Water Board and EPA have provided funding to study abandoned mines on the Chorro watershed. This study has already identified chromium and nickel as metals of concern in the watershed and will ultimately result in recommendations for remediation.

U.S. Department of Agriculture (USDA) Hydrologic Unit Area Water Quality Grants--The USDA has provided funding to support SCS technical assistance in the watershed ($140,000/year), Cooperative Extension adult and youth watershed education programs ($100,000/year), and cost sharing with farmers and ranchers ($100,000/year) for five years.

NPDES Permits

CWA Section 301(h)--This waiver to Federal Clean Water Act requirements remains in effect for the Morro Bay-Cayucos wastewater discharge facility as long as monitoring studies currently in place do not detect that the discharge is resulting in significant impacts to the environment. The facility began chlorinating the discharge after monitoring detected high coliform counts near the area of discharge.

California Men's Colony (CMC)--CMC has an NPDES permit to discharge effluent into Chorro Creek approximately nine miles upstream from the estuary. Though this is a potential source of water quality concern for the watershed and estuary, the discharge is generally regarded as a benefit to the system. The California Department of Fish and Game requires by agreement that at least 0.75 cubic feet per second of this discharge remain in the creek to support fish. Increasing demand for this water for reclamation projects, including a County golf course in the watershed, may further jeopardize water availability in the drainage.

U.S. Army Corps of Engineers (COE)--The COE conducts regular dredging at the mouth of Morro Bay to maintain the channel in a passable and safe state. The COE obtains waste discharge requirements from the Regional Water Board and water quality certifications from the State Water Board for dredging operations.

CWA Section 404 permits--Dredging activities conducted by other agencies which affect wetlands in and associated with Morro Bay are subject to the

Section 404 permitting process. For example, proposed dredging by the Department of Parks and Recreation to expand the small boat marina in Morro Bay will need to comply with any conditions placed on the permit by responsible agencies. Other dredging activities in the Bay include construction of new waterfront buildings in the City of Morro Bay, where eelgrass habitat can be disturbed as a result of construction activities. The Section 404 process provides a mechanism to ensure that these impacts can be mitigated properly. Other than the NPDES permitting, which has good results, the other programs are in progress and it is too soon to evaluate results.

2. Question

The nomination cites the "Morro Bay Watershed Enhancement Plan" prepared by USDA as a major success in addressing the estuary's top priority problem but does not describe the plan. Indicate what agencies or public entities are involved in implementing the plan, or show how this plan would be used in the development of a Comprehensive Conservation and Management Plan (CCMP).

Response

The "Morro Bay Watershed Enhancement Plan" (Appendix 3) describes two basic approaches to erosion and sedimentation control on the watershed. The first approach describes Best Management Practices to reduce soil erosion on land in the drainage, including roads, brushland, rangeland, pastures, and riparian and urban areas. Recommended practices include fencing, deferred grazing, riparian vegetation management, conservation tillage, construction site erosion control, and others.

The second approach includes construction of sediment basins or traps on the lower watershed to prevent soil which leaves the land from entering the Bay. Recommended sites included lower Chorro Creek and Warden Lake on the Los Osos Creek drainage. The plan recommended that both approaches be used in combination to address sedimentation problems on the watershed.

SCS is currently implementing the first approach using funding from CWA Section 319(h) and Hydrologic Unit Area water quality grants as described above, as well as cost sharing funds administered through the Coastal Commission and fish habitat restoration funds from the State Wildlife Conservation Board. One of the identified sedimentation trap sites on lower Chorro Creek has been purchased through funding from the State Department of Transportation's environmental mitigation fund and the Coastal Conservancy. Funding for implementation of this project is not yet available. This plan will provide a strong foundation with minor enhancement, to address sedimentation issues in a CCMP, and that implementation will continue consistent with any recommendations.

3. Question

State and local activities could be more fully described to enable an analysis of the current status of participating agencies, schedule/status, findings, implementation, compliance, and enforcement data for the various programs.

Response

State activities currently underway in the Morro Bay watershed include:

RWQCB--The Regional Water Board has dedicated one full-time person to Morro Bay project management. This position includes contract management for Section 319(h) projects, implementation of water quality monitoring as part of paired watersheds study, instream habitat monitoring, back bay bacterial monitoring, and participation in NPS program with the California Coastal Commission. Other actions include the Abandoned Mines Study, Toxic Sediment Monitoring Study, and issuance of a Cleanup and Abatement Order to the County of San Luis Obispo regarding closure of the Los Osos Landfill on the Warden Creek drainage.

California Coastal Commission--In cooperation with the Regional Water Board is utilizing the Morro Bay watershed as the model watershed for development of a Non-Point Source Management Plan pursuant to Section 6217 of the Federal Coastal Zone Management Act Reauthorization Amendments of 1990.

California Military Department--The California Military Department has provided SCS with a $30,000 grant to prepare a management plan for management of Camp San Luis lands on Chorro Creek drainage.

Fish and Game Wildlife Conservation Board--This Board has provided a $48,000 grant to SCS for implementation of instream restoration measures on Camp San Luis property on Chorro Creek drainage. Fish and Game is actively involved in habitat enhancement and fisheries restoration in the watershed.

California Department of Transportation (CalTrans)--CalTrans has matched a Coastal Conservancy grant with $835,000 to purchase land on lower Chorro Creek to serve as a sediment trap/flood plain.

Coastal Conservancy--The Conservancy funded initial sedimentation and enhancement studies ($100,000), and has provided $400,000 to the SCS program for implementation of Best Management Practices on agricultural lands. This money is used for 90 percent of the costs incurred. The other 10 percent is met by the land owner. They provided $110,000 to acquire the Sweet Springs Preserve and develop and implement the enhancement plan. The Conservancy has also provided $610,000 as match with CalTrans environmental mitigation fund money to purchase land on lower Chorro Creek to serve as a sediment trap/flood plain.

State Department of Parks and Recreation--This Department has funded studies on the invasion of hoary cress in the lower Chorro Creek delta.

County of San Luis Obispo--The County has provided leadership for the Morro Bay Task Force (membership listed in Appendix 4). All agencies listed have contributed personnel time for participation for more than four years. The county has used oil mitigation funds for a part-time leadership position until now when a half-time position is budgeted for FY 1992-93.

Additional local programs and the activities of the Bay Foundation are discussed in the next two responses.

4. Question

The April 1992 letter updating Morro Bay's nomination primarily cited problems with land use (i.e., high human population density, high development pressures, and freshwater withdrawal pressures), but the nomination provides little information on these issues. The nomination could be improved by discussing what county and municipal efforts (especially land use planning programs) are in progress or planned independent of the NEP to protect the estuary, and whether they are being enforced.

Response

The County of San Luis Obispo has an approved local coastal program which includes a local coastal plan and three area plans which generally protect the watershed by restricting harmful development and protecting agricultural lands. Currently, land uses within the Morro Bay watershed are primarily addressed in the San Luis Obispo, Los Padres, and Estero Bay area plans. The Morro Bay estuary is located within the Morro Bay area plan which is scheduled to begin the update process in 1993 in coordination with the proposed management conference. The County, in consultation with the Bay Foundation, is going to be introducing a Geographical Information System (GIS) and satellite imagery technology into the planning process for the watershed.

Enforcement and management of development activities is conducted by both the County of San Luis Obispo and the City of Morro Bay. The County of San Luis Obispo has a resource management system which includes levels of severity which alert decision makers to upcoming resource deficiencies. A resource capacity study addressing water quantity and quality issues for an area within the watershed was recently completed and is currently going through the public hearing process. The County also requires on site stormwater retention for all developments in the area. In addition, the resource protection section of the San Luis Obispo County Planning and Building Department actively enforces zoning violations within the watershed. Furthermore, the City of Morro Bay recently adopted an ordinance restricting live-aboard vessels within the Morro Bay estuary.

5. Question

The nomination could be improved by including comprehensive review (e.g., citations, purpose, completion dates, and findings) of studies and programs which private institutions, such as the California Polytechnic University (Cal Poly) and the Bay Foundation of Morro Bay, have participated in.

Response

In this addendum, we have listed the major studies being performed in the watershed. We will not repeat that information here. However, the Bay Foundation of Morro Bay has developed a Morro Bay and estuaries research library at Cuesta College.

A working bibliography is also being developed by The Bay Foundation. A preliminary listing of the materials of the catalogued reports related to Morro Bay is attached (Appendix 2). This is about 1/4th of the citations in the system. The remainder deal with related estuarine studies indirectly applicable to concerns in Morro Bay.

Few studies have been conducted on the Morro Bay estuary by private institutions, although a few have been funded by public agencies. (California Polytechnic State University is a State university). The Bay Foundation was founded in 1989 to address this deficiency.

A study titled "Freshwater Influences on Morro Bay" was prepared for the Bay Foundation by The Morro Group and Tenera Environmental Services (June 1990). This study summarizes existing data on streamflow, underflow, and ground water, and identifies existing and future water diversion projects and their total withdrawals. It also identifies sensitive habitats and species of interest in the watershed, and summarizes potential water quality concerns in the Bay, including stormwater discharge, sedimentation, bacteria, and nutrients. This study was unable to evaluate the freshwater needs of the estuary because of the ongoing drought and lack of flow at the time of study. It identified in its summary a number of research needs, including additional study on the freshwater requirements to maintain a healthy estuarine system, and long-term monitoring of biological and physical parameters in the Bay and watershed.

Horn and Allen (1976), in a paper titled "Numbers of species and faunal resemblance of marine fishes in California Bays and Estuaries", compared the fish fauna present in Morro Bay to that of Mugu Lagoon, Colorado Lagoon, and Upper Newport Bay, all in southern California. Morro Bay had the largest seasonal diversity of fish species and biomass, while the most urbanized lagoon, Colorado Lagoon, had the least. Based on species diversity, Horn concluded that Morro Bay was a highly productive and comparatively pristine system, but noted that intensified land use in the watershed could result in pressures affecting Morro Bay in the future. Horn (1980) also described diel and seasonal fish composition in the back bay.

In a study of fish fauna in Morro Bay, Fierstine et al. (1973) documented 66 species in five different habitats. This study confirmed use of shallow water areas and tidal creeks as important spawning habitat for a number of species, including some of commercial importance.

A study by Behrens and Sommerville (1982) on impingement at the Pacific Gas and Electric Company intake screens identified 88 species of fish, bringing the total observed between this study and that by Fierstine to over 100 species.

Josselyn (1989) prepared "Biologist Resources of Morro Bay as Impacted by Watershed Development in Los Osos and Chorro Creek Watersheds". This document summarizes various key species utilizing the Bay, discusses distribution of eelgrass beds, and discusses potential effects of sedimentation on these species. He concludes that sedimentation has (1) degraded stream bottom and brackish marsh habitat in lower Chorro and Los Osos Creeks, (2) promoted invasion of marsh habitat by exotic plants,

(3) resulted in loss of steelhead and tidewater goby habitat, (4) caused loss of historic eelgrass bed areas along with declines in some of the species utilizing these areas.

Perspective Planning (1989) prepared a plan for the Audubon Society titled "Sweet Springs Marsh Resource Enhancement and Access Management Plan". This document includes observations that the freshwater marsh in the Sweet Springs area of Los Osos has expanded in the last ten years. This expansion is attributed to the high ground water table resulting from domestic input to septic systems in the area.

Jeff Hatiner of Phillip Williams and Associates undertook a study on the "Sedimentation Processes in Morro Bay, California" (June 1988). This study included preparation of bathymetric and topographic maps of the area, sediment coring, study of tidal circulation, and documentation of historical changes in bathymetry of the Bay and morphology of the delta. It concluded that sedimentation has been sufficiently rapid to warrant additional study and to initiate remediation measures. It estimated that 45,000 cubic years of sediment is deposited per year in the Bay.

The Land Conservancy of San Luis Obispo, a nonprofit organization dedicated to preservation of open space and agricultural lands, prepared a document titled "Baywood and Los Osos Greenbelt". This study identifies an open space belt surrounding the community of Los Osos which could provide permanent open space protection for the endangered Morro Bay Kangaroo Rat, and an "edge" for the community. Other sensitive species which could be afforded protection by this greenbelt include the Banded Dune Snail, Monarch Butterfly, Morro Blue Butterfly, Tidewater Goby, and Morro Manzanita.

A partial list of topics of senior projects and master's theses written by students at Cal Poly in recent years include: the influence of tidal height on growth of *Crassostrea gigas* (Blaylock et al., 1975), the harbor seal in Morro Bay (Cox, 1974), foraging activities of the American White Pelican (di Milo, 1983), a study of fish larvae in Morro Bay (Elliston, 1978), an ichthyoplankton survey of Morro Bay (Feeney, 1978), a study of fish collections from 1968 through 1969 (Kline, 1970), a one-year study of recreational clamming in the Bay (Mello, 1981), brant geese hunting on Morro Bay in 1983 (Reid, 1985), and age distribution of brant in Morro Bay (Saint-Amour, 1983).

Management Conference Structure

1. Question

The proposed Policy Committee appears duplicative of the Sponsoring Agency Committee and fails to include representatives of the Public Advisory Committee and the Technical Advisory Committee.

Response

The Policy Committee will consist of representatives from many arenas with the authority to make decisions and commit efforts for their respective agencies or groups. Policy Committee members would be able to meet often

and serve on task-oriented subcommittees as necessary. This large group includes regulators, dischargers, land use planners, agricultural interests, landowners, environmental group leaders, legislators (Federal, State, local) and representatives from the Technical Advisory Committee (TAC) and Public Advisory Committee (PAC). The Sponsoring Agency Committee is an "executive committee" of the Policy Committee, made up of four members who provide leadership and direction to the larger Policy Committee. The Sponsoring Agency Committee will likely be made up of a State Water Resources Control Board Member, Regional Water Quality Control Board Member, County Supervisor, and EPA Region 9 Manager.

2. Question

The role of the Morro Bay Task Force could be more clearly defined, and it would be helpful if its membership was listed.

Response

The Morro Bay Task Force includes staff level people from all agencies and interest groups with responsibilities, jurisdiction, or interest in the Morro Bay watershed. The group was designed as an exchange forum for information about the Bay. While some members are decision makers for their agency/group, the Task Force is intended as a vehicle to facilitate coordination and exchange of information without a decision-making role. The Task Force has been very successful in this role involving primarily staff-level members. As shown in the original NEP nomination package, the Task Force will provide the membership for the TAC and PAC when they are formed. Attached as Appendix 4 is the Morro Bay Directory and a current Task Force mailing list which indicates the organizations and individuals involved.

Experience on the Morro Bay Task Force will be very valuable in expediting the work of the Management Conference by its participants.

3. Question

The nomination could be improved by identifying specific goals, objectives, and potential action plans to be undertaken by the Management Conference.

Response

The Morro Bay Task Force spent considerable time in 1988 and 1989 to develop a goals statement which could be supported by all of the agencies and interest groups. This eight-page document is attached as Appendix 5 and is still applicable. Of course, while the responsibility of the Management Conference is to develop goals and objectives, the Morro Bay Task Force statement will be a useful reference in the Conference process.

Political Will and Financial Commitment

1. Question

The absence of information regarding State programs and efforts to protect the estuary questions the level of State support for this nomination. In addition, lack of information on local government efforts to protect the estuary, especially enforcement of land use plans, would seem to indicate local political will is weak.

Response

Many Federal, State, and local programs to protect the estuary have been initiated. State programs currently contributing significant financial support to the Morro Bay program have already been summarized above (Institutional Arrangements, No. 3). Another recent development is an agreement with the State Lands Commission (which had no previous presence in the Bay to monitor activities) to grant jurisdiction over areas it controlled to the California State Department of Parks and Recreation and the California State Department of Fish and Game.

As to the local and state political will, Appendix 6 (attached) contains the letters of commitment to the program from all of the involved State and local agencies and interest groups. The persistent commitment of the membership of the Morro Bay Task Force and the considerable progress resulting is an indication of the outstandingly strong will to achieve and carry out the goal of a management plan for the Bay. The large membership support of the Friends of the Estuary at Morro Bay is another resounding indication of very strong commitment to carry out the elements of a management plan.

2. Question

A commitment to provide an annual 25 percent non-Federal match during development of the Comprehensive Conservation and Management Plan (CCMP) is required in each nomination. This commitment is not evident in the nomination of Morro Bay. In addition, any evidence of the State's intention to commit resources toward implementation of the CCMP should be provided. This evidence will demonstrate a committed match given EPA's emphasis on convening new management conferences only in those estuaries where action is likely to result. While the nomination claims that local government will provide the non-Federal match, no official statement from elected or authorized local representatives substantiating this commitment was included.

Response

The commitment for the 25 percent non-Federal match is by means of local in-kind funding that is already available and being used. This comes from all State and local agencies in the Morro Bay Task Force.

Appendix 7 (attached) includes the proposed budget for an NEP management conference. This appendix includes the letters of commitment to continue this in-kind support, e.g., the Regional Water Board ($50,000 per year)

and City of Morro Bay ($10,000). Appendix 7 was prepared at the time of the initial nomination (1991), so although the dates will change, the proposal is still current. Included are letters of support to demonstrate that this will be covered. The State is committed to the eventual realization of a successful nomination of Morro Bay into the NEP.

CONCLUSION

This addendum supplements the original nomination package submitted to the U.S. Environmental Protection Agency in May 1991. We feel that all issues raised have been thoroughly addressed. Morro Bay is an example of a relatively unpolluted estuary in need of protection. A management conference for Morro Bay would provide a unique opportunity for a demonstration project for the implementation of pollution prevention measures. Lessening the threats to Morro Bay by implementing prevention measures is critical to the survival of this coastal resource in its present, relatively pristine state. It is crucial that measures are taken immediately to protect Morro Bay to preserve its resources and prevent further degradation. Convening a management conference is an essential step in protecting Morro Bay.

APPENDIX

1

MAPS OF THE WATERSHED

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Please contact the Bays and Estuaries Unit to view original color maps and graphics.

State Water Resources Control Board
(916) 657-0687

Exhibit 1
Supplementary Maps for
Morro Bay Estuary and its Watershed

Exhibit 1 A **Habitat Overview of Morro Bay**
Created by the Bay Foundation of Morro Bay through volunteer effort.
Printing, courtesy of Friends of the Estuary.

Exhibit 1 B **Morro Bay Watershed Generalized Land Use**
Created by the Bay Foundation of Morro Bay through volunteer effort.
Printing, courtesy of Friends of the Estuary.

Exhibit 1 C **Sedimentation in the Delta Region of Morro Bay**
Created by the Bay Foundation of Morro Bay through volunteer effort.
Printing, courtesy of Friends of the Estuary.

Exhibit 1 D **Morro Bay Region Land Ownership**
Created by the Bay Foundation of Morro Bay through volunteer effort.
Printing, courtesy of Friends of the Estuary.

Exhibit 1 E **Detailed Land Use for the City of Morro Bay**
Created by the City of Morro Bay.
Copies, courtesy of Bob Semonsen, Bay Foundation of Morro Bay.

Exhibit 1 F **Detailed Land Use for the Unincorporated area of Los Osos**
Created by Bob Semonsen of the Bay Foundation of Morro Bay.
Printing, courtesy of Friends of the Estuary.

Data for the various color images was obtained from the following sources:

Land Ownership
"Coastal Stream Diversion Project Environmental Impact Report" 1992
Prepared for the City of Morro Bay by Robert H. Born Consulting Engineers

Bathymetric Data and General Habitat Regions
"Sedimentation Processes in Morro Bay" 1988
By Dr. Jeff Haltiner of Philip Williams & Associates

General Watershed and Urban Boundaries
"Erosion and Sediment Study, Morro Bay Watershed", Sept 1989
by: USDA Soil Conservation Service

Park Boundaries
"Montana De Oro State Park General Plan" 1988
"Map of the City of Morro Bay" 1989

General Agricultural Boundaries
"Erosion and Sediment Study, Morro Bay Watershed", Sept 1989
by: USDA Soil Conservation Service

Major Stream Delineations and Fresh and Brackish Areas
"Freshwater Influences on Morro Bay", June 1990
by: The Morro Group

Mariculture Boundaries within Morro Bay
"Oyster Mariculture In Morro Bay"
by: Tom Richards, Cal Poly University

Chorro Delta Background image
(1990 Infrared aerial photograph)
From the Bay Foundation of Morro Bay

Marsh Plain Boundaries and Mud flat depositional features
From "Evolution of Morro Bay Tidal Channels 1884 to 1990"
A State of the Bay Conference Report by Dr. Donald Asquith of the Morro Group.

Insert Image of the Bay Region Created by Bay Foundation processing of Satellite digital data.

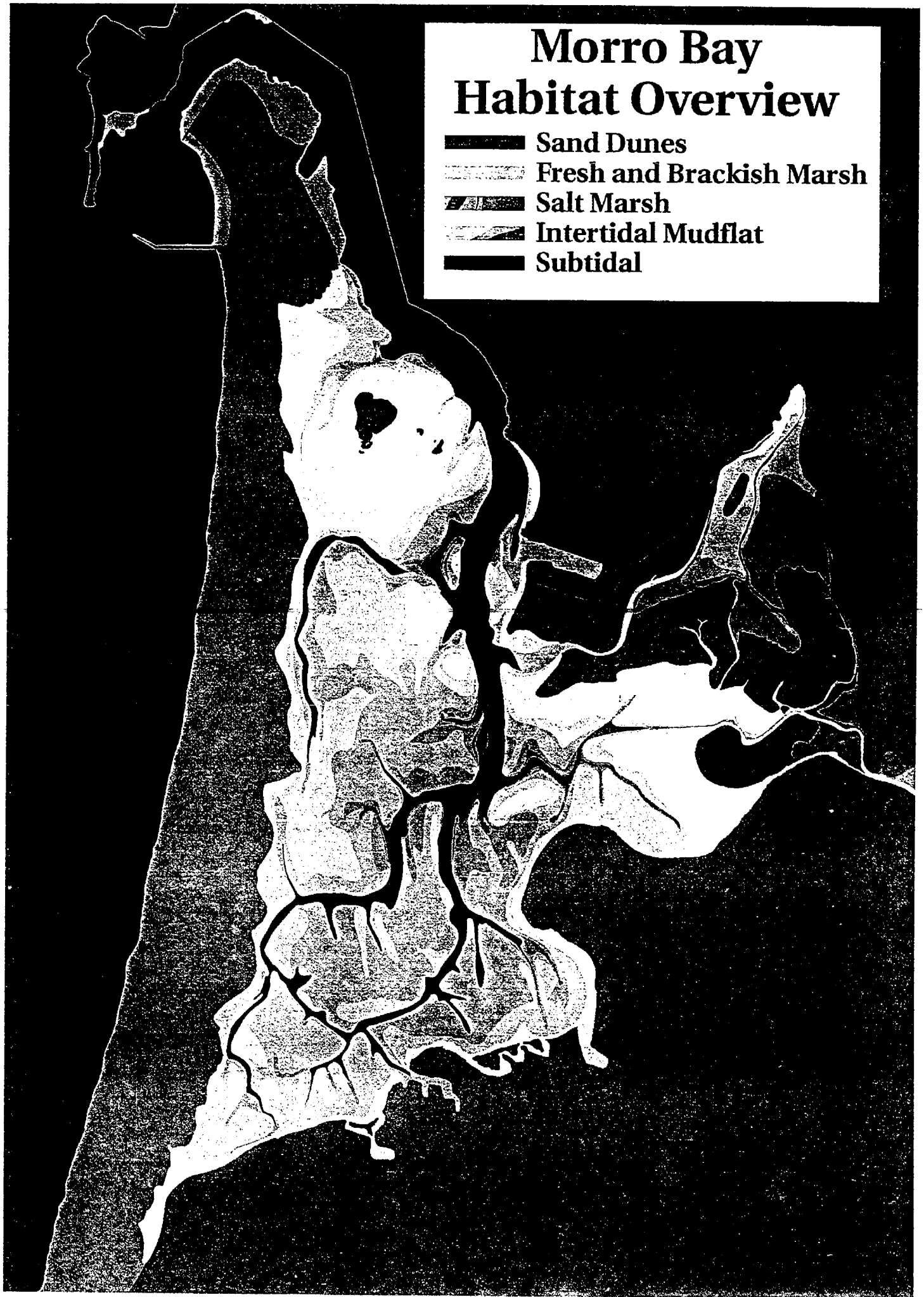

Morro Bay
Habitat Overview
Sand Dunes
Fresh and Brackish Marsh
Salt Marsh
Intertidal Mudflat
Subtidal

Exhibit 1 A

Derived from data presented in the U.S. Fish & Wildlife Service NATIONAL WETLANDS INVENTORY

	Acres	Miles
Morro Bay South (U.S. Fish & Wildlife Ecological System Designations)		
Estuarine Subtidal Open Water Artificial	6.014	
Estuarine Subtidal Open Water Subtidal	464.658	
Estuarine Intertidal Aquatic Bed Irregularly Exposed	1,032.590	
Estuarine Intertidal Beach Bar Regular	37.585	
Estuarine Intertidal Emergent Regular	778.796	
Estuarine Intertidal Emergent Irregular	241.091	
Estuarine Intertidal Flat Irregularly Exposed	8.465	
Estuarine Intertidal Steambed Irregularly Exposed		5.646
Marine Subtidal Open Water Subtidal	1,445.273	
Marine Intertidal Intertidal Regular	128.310	
Marine Intertidal Beach Bar Irregular	114.928	
Marine Intertidal Rocky Shore Irregular		1.487
Palustrine Emergent Artificial Saturated Seasonal	7.036	
Palustrine Emergent Intermittently Flooded	53.599	
Palustrine Emergent Saturated Semipermanent	73.014	5.018
Palustrine Forested Intermittently Flooded	83.253	57.780
Palustrine Forested Saturated Semipermanent Seasonal	4.898	
Palustrine Open Water Artificial	4.467	
Palustrine Open Water Artificial Intermittently Exposed	6.571	
Palustrine Open Water Intermittently Exposed	0.643	
Palustrine Scrub Shrub Intermittently Flooded		6.962
Palustrine Scrub Shrub Saturated Seasonal	10.198	
Riverine Lower Perennial Open Water Intermittently Exposed		1.394
Riverine Upper Perennial Stream Bed		0.594
Riverine Intermittent Intermittently Flooded		34.182
Upland	34,454.195	0.143
West Morro Bay South (U.S. Fish & Wildlife Ecological System Designations)		
Marine Subtidal Open Water Subtidal	37,163.512	
Marine Intertidal Intertidal Regular	34.917	
Marine Intertidal Beach Bar Irregular	27.327	
Marine Intertidal Rocky Shore	55.181	1.809
Marine Intertidal Rocky Shore Irregular	8.967	
Palustrine Forested Intermittently Flooded		2.476
Upland	1665.439	

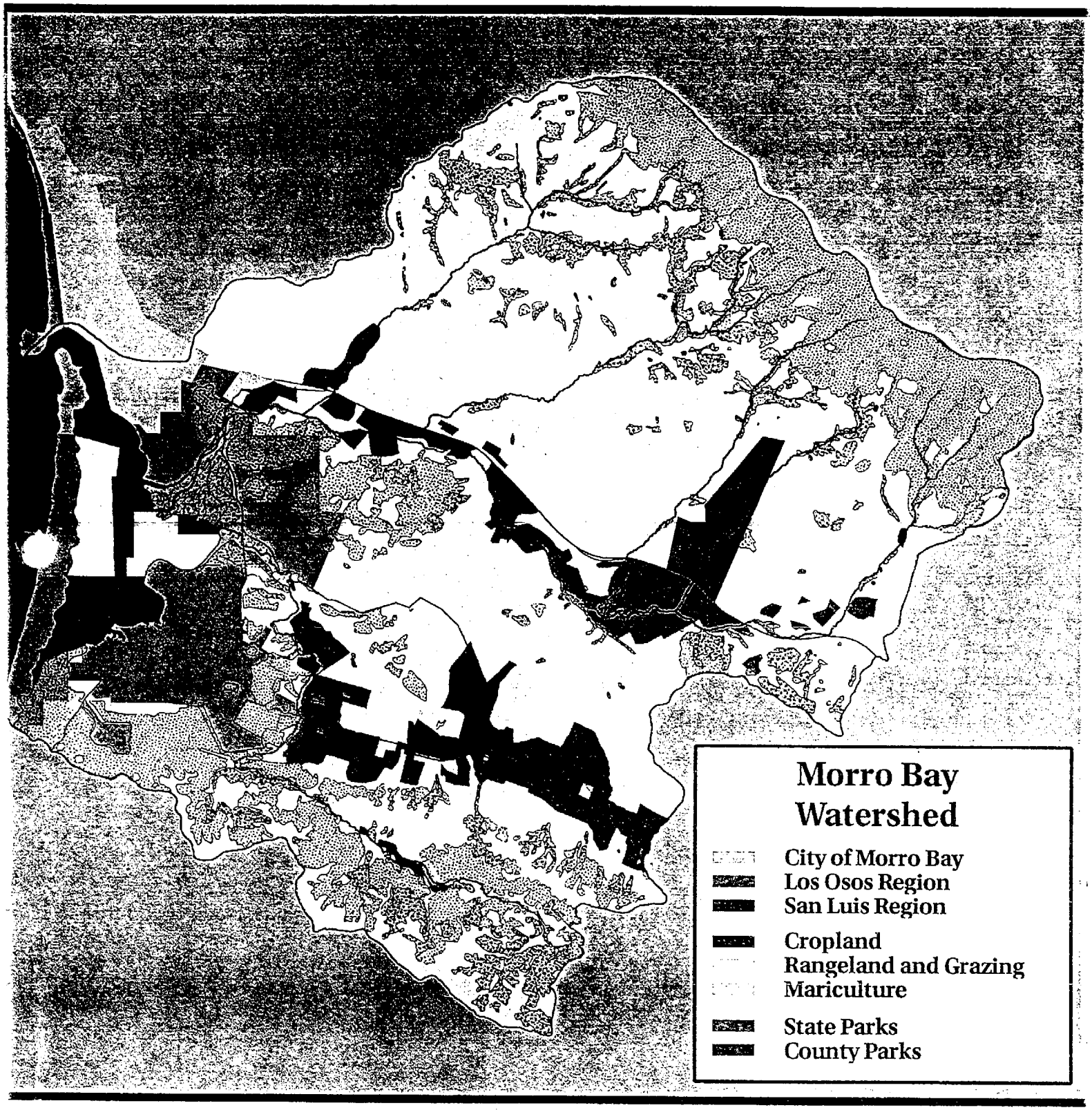

Morro Bay
Watershed
City of Morro Bay
Los Osos Region
San Luis Region
Cropland
Rangeland and Grazing
Mariculture
State Parks
County Parks

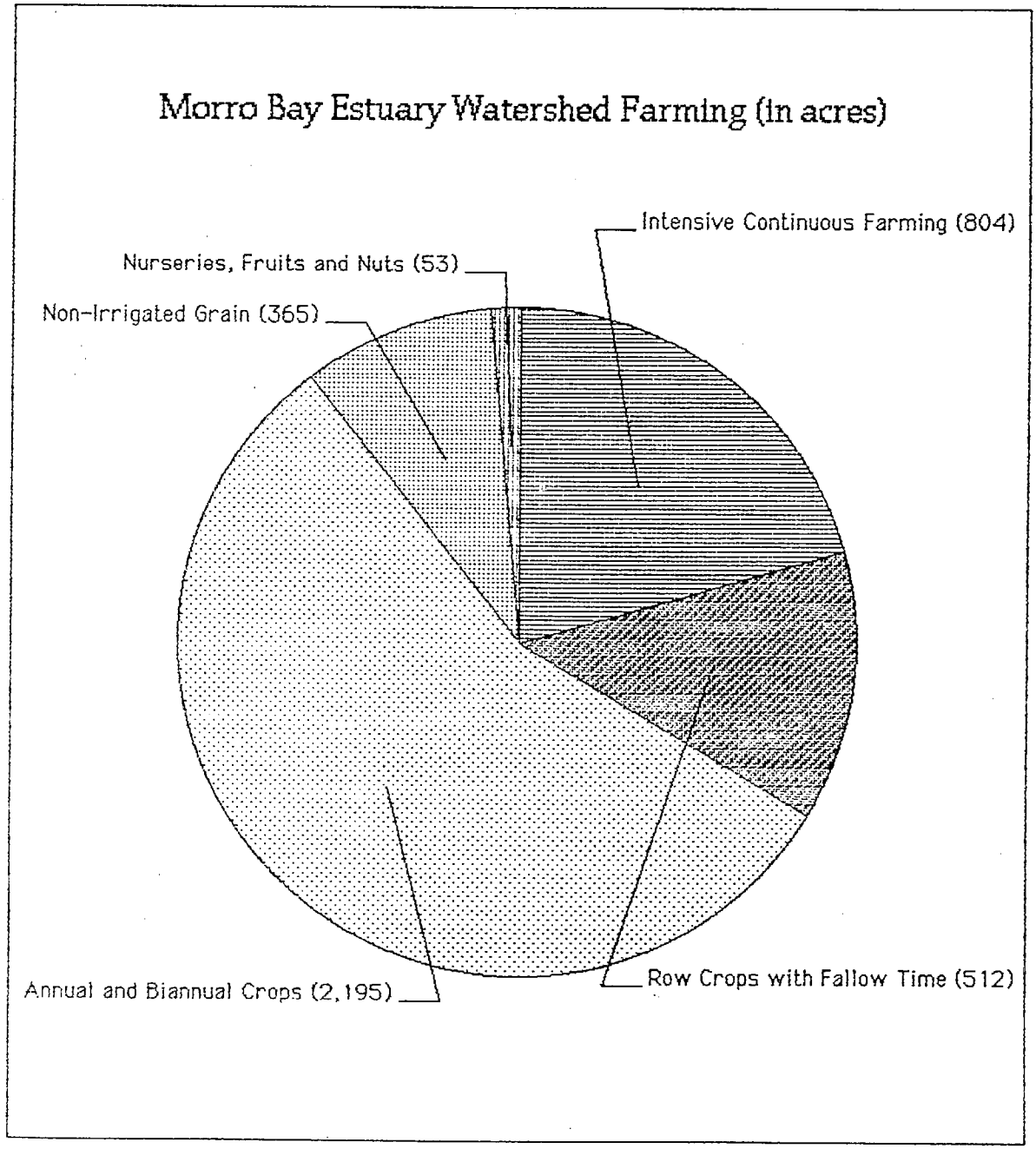
Exhibit 1 B

The Incorporated City of Morro Bay has a population of approximately 10,000.

The Unincorporated Los Osos Region has a population of approximately 15,000.

The San Luis region contains a State Prison a County Jail, a National Guard Base and a Community College. These facilities makeup the bulk of the population of this region, which a approximately 10,000.

In addition to the large parks shown on the Exhibit B map, there are numerous small city and county parks within the watershed. The Federally owned land in the upper watershed contains a portion of the Los Padres National Forest. (See the land ownership map for Federal ownership boundaries).



Sedimentation in the Delta Region of Morro Bay

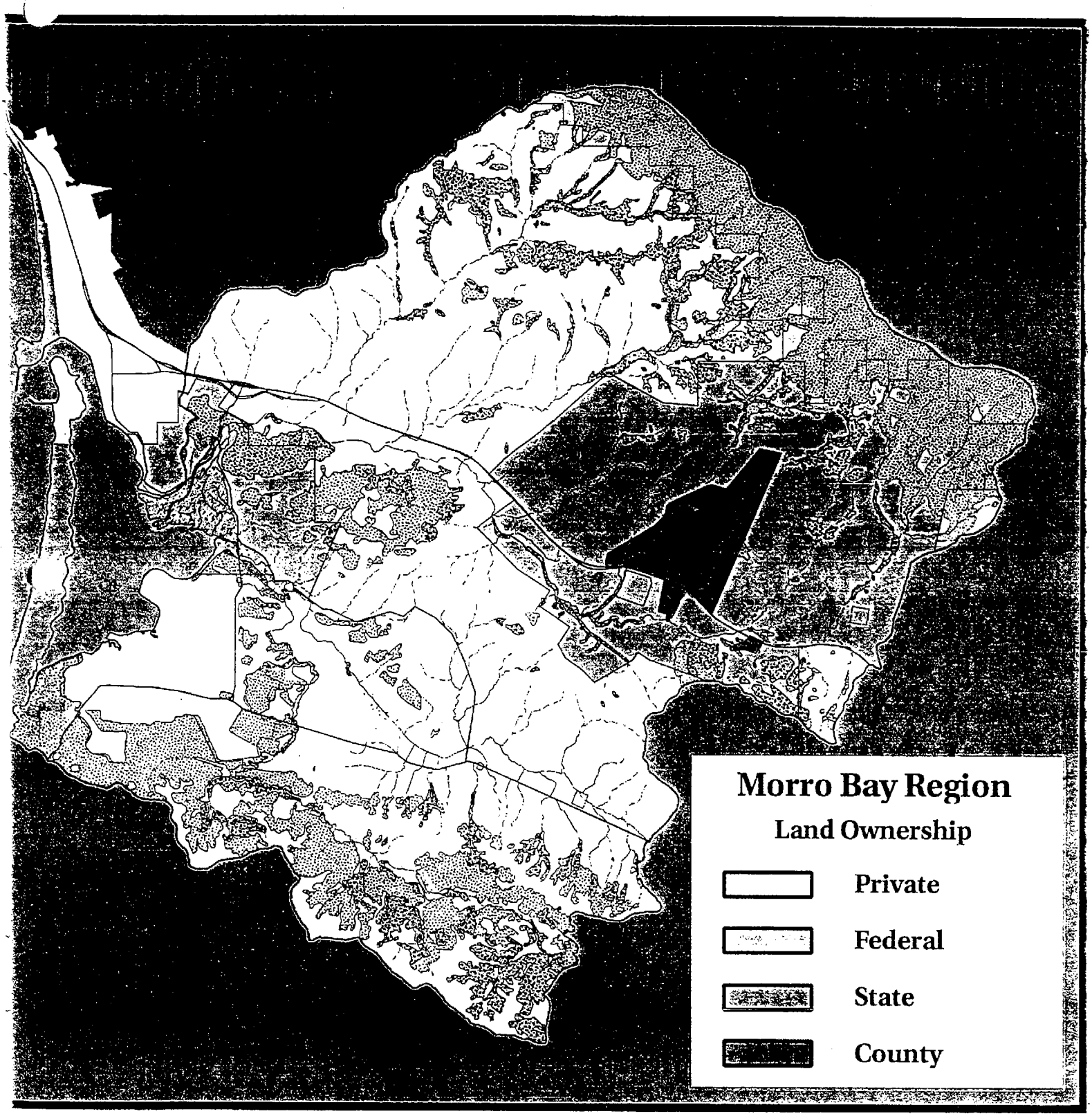
Exhibit 1 C

Chorro Creek is one of two major drainages entering Morro Bay. The creek drains an area of 30,000 acres and has formed an extensive "bird-foot" delta as it enters Morro Bay (Chipping 1974). The delta is generally defined as the seaward extent of vegetation. Based on this definition, the delta has increased in size from approximately 280 acres in 1897 to 423 acres in 1965 (Gerdes et al, 1974). Most of the increase is related to the increase in soil erosion within the watershed.

For the most part, the plant community within the Delta is dominated by tidal marsh vegetation, particularly pickleweed, Salicornia virginica. This plant is tolerant of tidal inundation and saline soils. In the upper reaches of the delta and above the reach of normal tides, pickleweed is replaced by willows and other brackish and freshwater wetland vegetation (Showers 1986). An introduced species, hoary cress (Cardaria draba), has also colonized the transitional zone between the salt marsh and freshwater wetland habitats.

Haltiner (1988) documented the extensive sedimentation that has occurred within Morro Bay and the Chorro Delta. He reached the conclusion that the expansion of the Delta has slowed because the edge has reached a stable, deep-water channel. Consequently, sediment reaching this point enters the Bay circulation system rather than being deposited on shallow mudflats. Rather than building outward into the Bay, Haltiner concluded that major portions of the delta were building upward by as much as two to three feet as a result of channel overtopping and sediment deposition during major flood events.

Accelerated sedimentation has also been taking place in other portions of the bay. If the conclusions of Dr. Asquith, who mapped the delta using historic charts and aerial photographs, and Dr. Haltiner are correct, then these other areas may be subject to even greater problems due to more rapid transport of sediment from the delta region.


Morro Bay Region
Land Ownership
Private
Federal
State
County

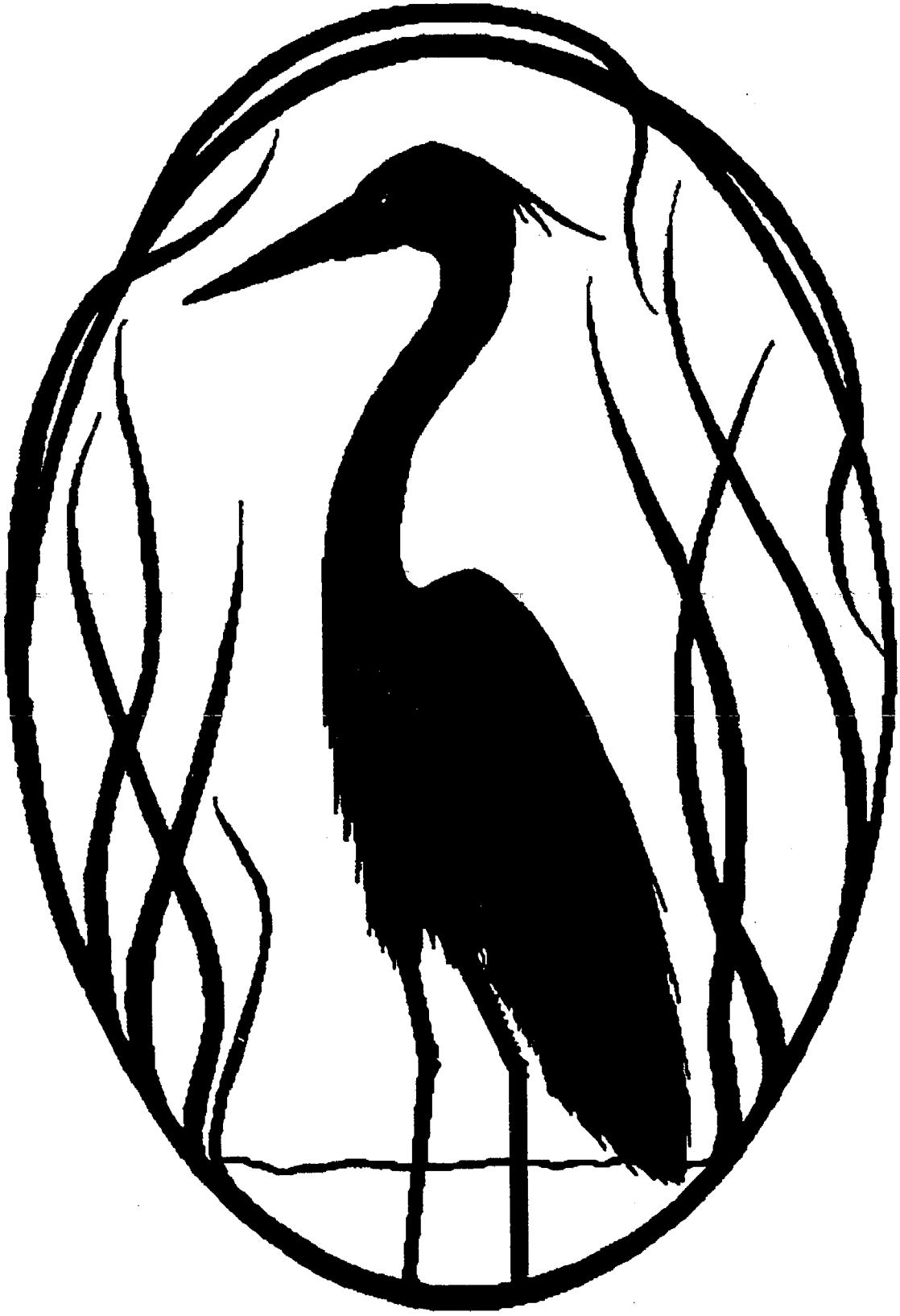
APPENDIX

2

BIBLIOGRAPHY

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Morro Bay Estuary Bibliography



A Publication of the Bay Foundation of Morro Bay

1992

Adams, J. Rodger. 1972 "Marine Life In The Morro Bay Power Plant Discharge Canal" Pacific Gas and Electric Company, San Francisco. 36 pages #618

Adams, James R., Price, Donald G., and Clogston, Fred L. 1974 "An Evaluation Of The Effect Of Morro Bay Power Plant Cooling Water Discharge On The Intertidal Macroinvertebrate Community" Pacific Gas and Electric Co., Department of Engineering Research. San Ramon, California QH 545.E38 A3 134 pages * #619

Anthony, Renee., P. Jagger, and R. Briggs. 1988 "Morro Bay Bacterial Study, 1986-1987 A Cleanup And Abatement Study" Regional Water Quality Control Board, Central Coast Region. QH 545.S49 A5 * #955

Arnold, Carol. 1987 "Staff Recommendation For The Morro Bay Watershed Program: Los Osos And Chorro Creeks Enhancement Plans" State Coastal Conservancy. 10 pages #909

Ashbaugh, J. B., L. K. Schicker, and W. G. Roalman. 1988 "Sweet Springs Marsh Resource Enhancement And Access Management Plan" Prepared for Morro Coast Audubon Society and the California Coastal Conservancy by Perspective Planning. #1626

Asquith, D. et al. 1990 "Freshwater Influences On Morro Bay" Prepared for The Bay Foundation of Morro Bay by The Morro Group and Tenera Environmental Services. #625

Asquith, Donald. 1991 "Evolution Of Morro Bay Tidal Channels, 1884 To Present" pages 7-2.22-7-2.38 in State of the Bay Proceedings 1992 * #803

Atlantis Scientific. 1984 "San Bernardo Creek Dam And Hydropower Project" Beverly Hills. California #1705

Bailey Jane H. and Gates, Dorothy L. 1982 "Morro Bay's Yesterdays, Vignettes Of Our City's Lives And Times" El Morro Publications, Morro Bay, California. #1678

Baiocco, J. C. 1978 "The Fish Species Found In Both San Luis And Los Osos Creek Estuaries And An Evaluation Of The Current Status Of Eucyclogobius Newberryi" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 23 pages #1627

Barclay, L. A. 1975 "Fishery Survey Of Six Coastal Streams And The Salinas River Drainage, San Luis Obispo County" California Polytechnic State University, Department of Biological Sciences Report. #361

Barnes, Vera Ashby. 1963 "An Ecological Study Of The Intertidal Area And Estuary Of Morro Bay State Park And Vicinity" 120 pages #1697

Barnes, Vera Ashby. 1964 "An Ecological Study Of The Intertidal Area And Estuary Of Morro Bay State Park And Vicinity" 120 pages #824

Barnes, Vera Ashby. 1965 "A Study Of The Terrestrial Plants And Animals Of Morro Bay State Park And Vicinity" 187 pages #825

Behrens, D. W. and D. C. Sommerville. 1982 "Impingement Studies At Morro Bay Power Plant" Pacific Gas and Electric Company, Department of Engineering Research Report 026.22-80.1 127 pages #781

Behrens, David W. 1980 "Pacific Coast Nudibranchs, A Guide To The Opisthobranchs Of The Northeastern Pacific" Sea Challengers, Los Osos 112 pages #822

Blaylock, W. and R. E. Fairfax. 1975 "The Influence Of Tidal Height On The Growth Rate Of Crassostrea Gigas In Morro Bay" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 33 pages #1628

Bodkin, J. L and G B. Rathbun. 1989 "Morro Bay Sea Otter Study Annual Report 1988" U.S.Fish and Wildlife Service 29 pages #1172

Bodkin, J. L and G. B. Rathbun. 1988 "Morro Bay Sea Otter Study Annual Report 1987" U.S.Fish and Wildlife Service 30 pages #1171

Boland, John Michael. 1988 "The Ecology Of North American Shorebirds: Latitudinal Distributions, Community Structure, Foraging Behaviors, And Interspecific Competition" [Ph.D. Dissertation] University of California, Los Angeles. 256 pages #365

Born, Barrett and Associates. 1985 "Reconnaissance Level Investigation For The Proposed San Bernardo Creek Project" Prepared for the City Of Morro Bay. #766

Bowker, L. and Hensley. 1986 "An Assessment Of The Impacts Of Siting A Sewage Treatment Facility And Recharge Basins On The Los Osos Creek Drainage" Included in: The Morro Group"County Service Area-9 Waste water Treatment Facilities Environmental Impact Report" Appendix D-7. #366

Brady, K. 1977 "Some Soil Relationships Of The Morro Bay Sand Dunes" [M.S. Thesis] California Polytechnic State University. #994

Brown and Caldwell. 1974 "Preliminary Groundwater Basin Management Study, San Luis Obispo County Service Area 9" prepared for the County of San Luis Obispo 32 pages #1135

Brown and Caldwell. 1981 "Preliminary Water Management Plan, City Of Morro Bay" Prepared for the City of Morro Bay, February 13, 1981. #368

Brown and Caldwell. 1983 "Los Osos Baywood Park Phase I Water Quality Management Study" prepared for San Luis Obispo County. Volume I-Project Report 100 pages and Volume II-Appendices #1136

Brown and Caldwell. 1984 "Phase II Facilities Planning Study, San Luis Obispo County Service Area No. 9, Los Osos And Baywood Park" prepared for the County of San Luis Obispo, January 16, 1984. #1083

Brown and Caldwell. 1984 "Supplement To The Los Osos Baywood Park Phase II Facilities Planning Study Project Report And Environmental Impact Statement" September #1066

Bruce, Albert W. 1960 "Five Years Experience Making Fresh Water From Sea Water At The Morro Bay Power Plant" Presented at the Colloquium on the Desalting of Water at the California Institute of Technology. Pasadena, California. May 5-6, 1960. #2173

California Polytechnique State University 1972 "Utilization Of The Morro Bay Area State Parks For The Study And Teaching Of Marine And Estuarine Ecology: A Design Study. San Luis Obispo, California" 'This study was done by a Design for Planners class in the School of Architecture and Environmental Design at California Polytechnic University, San Luis Obispo during Spring quarter 1972 and completed in September 1972. LC 1021.U8 * #2257

California Coastal Conservancy. 1986 "The California Coastal Conservancy" HT 393.C3 C3461 * #2345

California Department Of Corrections. 1981 "California Mens Colony Reactivate West Facility Draft Environmental Impact Report. " October. #2174

California Department Of Fish and Game. 1966 "Report Of The Natural Resources Of Morro Bay And Proposal For Comprehensive Area Plan" State of California , the Resources Agency, QH 105.C2 R4 37 pages * #2319

California Department Of Fish and Game. 1989 "Memorandum To State Water Resources Control Board, Subject: Water Applications 24239, 24245 And 27386, Chorro Creek Underflow" City of Morro Bay, San Luis Obispo County: October 18, 1989. #370

California Department Of Health Services Santa Barbara District. 1985 "Sanitary Investigation Of Shellfish And Water Quality, Morro Bay. September 1984 And January 1985" California Regional Water Quality Control Board, Central Coast Region. #957

California Department Of Parks and Recreation. 1986 "Marine Life, Resource Inventory, Morro Bay Area State Parks" California Polytechnic State University, Biological sciences department 41 pages #814

California Department Of Parks and Recreation. 1986 "Resource Inventory, Morro Bay State Park" California Department of Parks and Recreation, Natural Heritage and Cultural Heritage Sections. 68 pages #958

California Department Of Parks and Recreation. 1987 "Los Osos Oaks State Preserve, Preliminary General Plan" 68 pages #918

California Department Of Parks and Recreation. 1988 "Morro Bay State Park, Preliminary General Plan" California Department of Parks and Recreation. 152 pages #920

California Department Of Public Health, Bureau Of Sanitary Engineering. 1951 "Morro Bay Investigation Oyster Fisheries" Water quality study.16 pages #637

California Department Of Public Health, Bureau Of Sanitary Engineering. 1953 "Investigation Of Certain Oyster Growing Areas In Morro Bay" [13] leaves, 1 folded map leaf. Typescript (carbon). November 3-10, 1953. G4814 H3 #629

California Department Of Water Resources. 1955 "Bulletin No. 18, San Luis Obisbo County Water Investigation" Volumes 1 and 2. Sacramento California #1707

California Department Of Water Resources. 1960 "Morro Bay State Park Water Supply Investigation" Interdepartmental communication to California Division of Beaches and Parks. March 1960. #2177

California Department Of Water Resources. 1963 "Feasibility Of Serving The San Luis Obispo County Flood Control And Water Conservation District From The State Water Facilities" Bulletin No. 119-7. August. #2179

California Department Of Water Resources. 1969 "Additional Sources Of Water For The Central Coastal Area: Desalting Sea Water, Weather Modification And Water Reclamation" Southern District Technical Information Record 1376-10-B-4. April 1969. #2180

California Department Of Water Resources. 1969 "Cost Of Water Supply Alternatives: Central Coastal Area" Southern District Technical Information Record No. 1376-10-B-6. October. #2181

California Department Of Water Resources. 1969 "Water Quality Conditions, Coastal Region, San Luis Obispo County" Memorandum Report. October. #2182

California Department Of Water Resources. 1970 "Geophysical Survey Of Morro Bay" 7 leaves, 3 fold. leaves of plates: ill. ; 28 cm. Office report. Morro Bay California #626

California Department Of Water Resources. 1972 "Sea Water Intrusion: Morro Bay Area, San Luis Obispo County" The Resources Agency, State of California. Bulletin 63-6 104 pages #2183

California Department Of Water Resources. 1973 "Los Osos Baywood Ground Water Protection Study" Southern District Report. 46 pages #1140

California Department Of Water Resources. 1975 "Preliminary Evaluation Of The Safe Yield Of Whale Rock Reservoir" Southern District Technical Information Record 1080-80781-B-I. June. #2187

California Department Of Water Resources. 1979 "Morro Bay Sandspit Investigation" Southern District Report 64 pages #1143

California Department Of Water Resources. 1981 "Aquifer Tests Conducted At The City Of Morro Bay Wells In Lower Chorro Valley, May 12-14, 1981" Technical Information Record 1335 A-I July. #2215

California Department Of Water Resources. 1981 "Evaluating The Impact Of Interference On The City Of Morro Bay's Wells During Drought" November. Technical Information Record 1335 A-2 #2216

California Department Of Water Resources. 1982 "A Monitoring Program For Morro Bay" May. Technical Information Record 1335 B-2 #2218

California Department Of Water Resources. 1982 "Estimate Of Morro Bay Well Production Capacity During Drought" May. Technical Information Record 1335 B-3 #2219

California Department Of Water Resources. 1982 "Ground Water Basin Recharge Program In Morro Bay Area" May. Technical Information Record 1335 B-5 #2221

California Department Of Water Resources. 1982 "Morro Bay Area Water Management Plan" During the past 20 years, a variety of studies have been conducted on the status of water supply for the city of Morro Bay and surrounding communities. Many of the previous studies have been summarized in this report. #1220

California Department Of Water Resources. 1982 "Morro Bay Investigation Reconnaissance Cost Estimates Of Local Water Supply Projects" May. Technical Information Record 1335 C-2 #2223

California Department Of Water Resources. 1982 "Preliminary Evaluation Of Population And Water Demand Projections For The City Of Morro Bay" Revised May. Technical Information Record 1335 C-1 #2222

California Department Of Water Resources. 1982 "Preliminary Evaluation Of The Locations Of The City Of Morro Bay's Wells" May. Technical Information Record 1335 B-4 #2220

California Department Of Water Resources. 1982 "Preliminary Evaluation Of Water Supplies In The Morro Bay Area" May. Technical Information Record 1335 B-1 #2217

California Department Of Water Resources. 1986 "San Luis Obispo County Master Water Plan Update" Prepared in cooperation with San Luis Obispo County Flood Control and Water Conservation District. Southern District Report. March. 107 pages #374

California Department Of Water Resources. 1989 "Geohydrology And Management Of Los Osos Valley Groundwater Basin, San Luis Obispo County" 66 pages #959

California Division Of Water Resources. 1956 "Investigation Of Sources Of Water Supply For California Mens Colony, San Luis Obispo, California" May. #2175

California Polytechnic State University. 1974 "The Natural Resources Of Morro Bay" Biological sciences department for California Department of Fish and Game, 103 pages #813

California Regional Water Quality Control Board. 1980 "Order No. 80-42, NPDES No. CA0047856 Adopted 24 November 1980, For California Department Of Corrections California Men's Colony, San Luis Obispo County" 7 pages #1168

California Regional Water Quality Control Board. 1983 "Los Osos Baywood Park Area Basin Plan Amendment" Staff Report, August #1038

California Regional Water Quality Control Board. 1983 "Resolution 83-13, Revision And Amendment Of Water Quality Control Plan By The Addition Of A Prohibition Of Waste Discharge From Individual Sewage Disposal Systems Within The Los Osos/ Baywood Park Area, San Luis Obispo County" adopted 16 September #1030

California Regional Water Quality Control Board. 1984 "Los Osos Baywood Park Area Consideration Of An Immediate Prohibition Of Waste Discharge From Additional Individual Waste Water Disposal Systems" Central Coast Region. Staff Report, November #1031

California Resources Agency. 1976 "Morro Bay, Los Osos Oaks And Montana De Oro Teacher's Guide" part 1 Before and after the field trip, 61 pages Part2 What to do at the Park, 23 pages Part 3, Data Book, Land and Life, and Chumash Culture 23 pages #816

California Water Resources Control Board and Office Of Environmental Protection. 1989 "National Estuary Program: The Nomination Of Morro Bay" Prepared by the Friends of the Estuary of Morro Bay for submission to U.S.Environmental Protection Agency. 49 pages * #982

California Water Resources Control Board. 1989 "Complaint Against California Polytechnic State University, Chorro Creek, San Luis Obispo County" Memorandum to files, December 19, 1989. #380

California Water Resources Control Board. 1989 "Revised Water Quality Control Plan For Enclosed Bays And Estuaries Of California" Sacramento, California #379

Carollo, J., Engineers. 1977 "Draft Environmental Impact Report For Morro Bay-Cayucos Waste Water Facilities" Walnut Creek, California #1167

Carr, Virgil E., Watkins, William D., John F. Musselman. 1986 "Ocean Outfall Study, Morro Bay, California, October 1985" Submitted to region IX shellfish specialist Davisville,RI Northeast Technical Services Unit QH 545.O33 C3 * #2227

Chandler, Philip Brian. 1977 "Geologic Elements For Urban Planning, Estero Bay, California" [M.S. Thesis] University of Southern California, Los Angeles. February. #2199

Chappell, P. P., J. L. Lidberg, and M. L. Johnson. 1976 "Report To The State Water Resources Control Board Summarizing The Position Of The California Department Of Fish And Game On Water Application 24120" California Department of Fish and Game Region 3. 39 pages #1169

Chipping, D. H. 1974 "Preliminary Description Of The Processes Of Morro Bay" California Polytechnic State University, Physics Department, San Luis Obispo, California. Referenced in: Conservation Planning Collaborative, 1975. #587

Chipping, D. H. 1979 "Chorro Delta: A Birdfoot Delta" California Geology Volume 32 pages 51-57 #586

Chipping, D. H. 1979 "Chorro Delta: A Birdfoot Delta" Professor Chipping, a geologist from California Polytechnic State University, used historical U.S.Geological Survey maps and aerial photos to describe the delta at the mouth of Chorro Creek. This report includes a description of the various features of the delta channels, salt marsh, and intertidal mudflats. It provides some explanation for the mechanisms of development for various features. #1214

City Of Morro Bay. 1982 "Proposed Land Use Plan Of The Local Coastal Program" City of Morro Bay Community Development Department 231 pages * #1650

City Of Morro Bay. 1985 "Draft Environmental Impact Report For City Applications For Appropriative Water Rights To 1,723.5 Acre Feet Per Year Of Morro Creek And Chorro Creek Underflow" SCH No. 85032014, November. #1413

City Of Morro Bay. 1987 "Draft Environmental Impact Report For Appropriative Water Rights For Toro Creek Underflow" Prepared by McClelland Engineers. #765

City Of Morro Bay. 1990 "Final Environmental Impact Report For Recreational Boat Marina At The Inn At Morro Bay" submitted to city of Morro Bay. HT 393.C3 F5 * #2342

City Of Morro Bay. 1990 "Proposed Recreational Boat Marina At Inn At Morro Bay:" various staff reports and comments. Morro Bay, California: HT 393.C3 F52 * #2341

City Of Morro Bay. 1991 "Local Coastal Program: Land Use Plan And Implementing Ordinances" Prepared for and Certified by the California Coastal Commission. Various dates due to amendments. #966

Cleath, Timothy S. 1988 "Water Resources Study, Chorro Valley Ranch" San Luis Obispo, California TC 425.S3 C6 * #2265

Clemmer, John. 1962 "Archaeological Notes On A Chumash House Floor At Morro Bay" Central California Archeological Foundation. Report for Pacific Gas and Electric Co., San Francisco. #1286

Clogston, F. L. 1986 "Aquatic Biology Survey Report For The Twin Bridges Project Site" Prepared for California Department of Transportation. #386

Clogston, F. L. 1986 "Report On The Environment And Biota Of Los Osos Creek Estuary And Adjacent Portions Of Morro Bay" Included in: The Morro Group "County Service Area-9 Waste water Treatment Facilities Environmental Impact Report" Appendix D-9.14 pages #385

Condor Earth Technologies, Inc. 1989 "Description Of Field Procedures. Vibra Core Sampling Of Shallow Marine Sediments, Proposed New Marina Site, Inn At Morro Bay" Prepared for J. H. Edwards. #1539

Congdon, Justin D., and A. I. Roest. 1975 "Status Of The Endangered Morro Bay Kangaroo Rat" J. Mammal. 56(3) pages 679-683. #1688

Conservation Planning Collaborative, Inc. 1975 "A Coastal Watershed Environmental Management System: Morro Bay, California" CPC developed a comprehensive master plan for Morro Bay, including recommendations for a watershed based governmental organization and a variety of technical recommendations. In the preparation of this report, thirty nine maps were prepared showing a variety of land use features, physical and biological resources. #1215

Converse Consultants. 1985 "Morro Bay Hydrogeology Study" Included in: "Environmental Impact Report for City Applications for Appropriative Water Rights to 1, 723.5 Acre Feet per Year of Morro Creek and Chorro Creek Underflow (SCH#85032014)" #387

Cox, G. W. 1974 "The Harbor Seal In Morro Bay" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 13 pages #1631

Deneen, William L. 1975 "Morro Bay Ecology And Coastal Wetlands" 13 pages #828

Deutsch, D. 1987 "The Effect Of Sedimentary Grain Size Distribution Upon Benthic Marine Microorganisms" Draft [M.S. Thesis] California Polytechnic State University and Cuesta College. #589

Di Milo, M. 1983 "Foraging Activities Of American White Pelicans In The Morro Bay Estuary" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 12 pages #1632

Dickerson, Sharon Lewis. 1990 "Mountains Of Fire, San Luis Obispo County's Nine Sisters, A Chain Of Volcanic Peaks" EZ Nature Books, San Luis Obispo,California #1671

Dingler, J. R., Anima, R. J., Molzan, D. E., Luepke, G., and Peterson, C. L. 1982 "A Field Study Of Littoral Processes In Estero Bay, California" U.S.Department of Interior Geological Survey. Open File Report 82-537. GB458.8.F5 * #1237

Dubsky, P. A. 1974 "Movement Patterns And Activity Levels Of Fishes In Morro Bay, California As Determined By Ultrasonic Tagging" [M.S. Thesis] California Polytechnic State University, San Luis Obispo, 51 pages #389

Eabry, Steve. 1991 "Morro Bay Directory: An Annotated List Of Organizations With Responsibilities And/or Interests In The Morro Bay Watershed" 4th edition. San Luis Obispo, California QH 541.5 M3 M6 27 pages * #2311

Eabry, Steve. 1991 "Morro Bay, A Schizophrenic Personality" pages 1-2.3-1-2.11 in State of the Bay Proceedings 1992 * #786

Ecomar. 1975 "Predesign Oceanographic Study Report For The City Of Morro Bay" prepared for the City of Morro Bay, 595 Harbor St., Morro Bay, California #1239

Elliston, I. G. 1978 "A Study Of Fish Larvae In Morro Bay From June, 1977 To December, 1977" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 23 pages * #1634

Engelhardt, Z. 1933 "Mission San Luis Obispo In The Valley Of The Bears" Mission Santa Barbara. #999

Engineering-Science, Inc. 1986 "Phase I Sewerage Planning Study, County Service Area 9-los Osos, Baywood Park, Cuesta-by-the-Sea" Prepared for the County of San Luis Obispo, May, 1986. #1090

Engineering-Science, Inc. 1987 "Comprehensive Engineering Report: Los Osos Landfill" Prepared for San Luis Obispo Engineering Department. #927

Federal Emergency Management Agency. 1985 "Flood Insurance Study, City Of Morro Bay" Govt Doc No.: FEM 1.209:060307 Community number, 060307 18 pages #1543

Feeney, R. 1978 "An Ichthyoplankton Survey Of Morro Bay From January 20, 1977 To June 5, 1977" [Senior Thesis] California Polytechnic State University, San Luis obispo, California 36 pages #1635

Feldmeth, C. R., Prigge, B. A., Jenkins, T. M., Soly, D. L., Guthers, D. A., and Clements, R. F. 1989 "Biological Resources And Environmental Impact Analysis Of The Phase 2 Coastal Streams Diversion And Storage Project, San Bernardo Creek Dam" Claremont, California #1708

Fierstine, H. L., K. F. Kline and G. R. Garman. 1972 "Fishes Collected In Morro Bay, California Between January 1968 And December 1970" California Department of Fish and Game Bulletin 59(1) pages 73-88 #1535

Fierstine, H. et al. 1970 "A Guide To The Identification, Habits And Use Of Some Morro Bay Fishes" Compiled by students of Biology of Fishes (Zoology 322), California Polytechnic State University, San Luis Obispo, California #1636

Folsom, R. G. 1944 "Memorandum On Code Messages, San Francisco And Morro Bay. Berkeley, California" University of California, College of Engineering, 1944. 2 leaves ; 28 cm. IER series ; 3, no.34] HE-116-34 Title altered on cover: "Transmission of wave conditions by code" University of California, Berkeley. College of Engineering. Fluid Mechanics Division.Institute of Engineering Research series ; no. 3, issue no.34. Call number: 25.5 X-3 no.34 #624

Ford, R. L. 1993 "Magnitude And Frequency Of Geomorphic Processes In A Coastal Salt Marsh, Morro Bay, California" [Ph.D. Dissertation] Los Angeles, University of California. #1367

Ford, Richard. 1991 "Tide-driven Deposition On The Chorro-Los Osos Delta, Morro Bay, California" pages 7-4.49-7-4.5 in State of the Bay Proceedings 1992 * #805

Frank, A. F. W. 1963 "Statement Of Mission. U.S. Army Garrison, Camp San Luis Obispo, California" T/D 6A-6015. #1170

Frankel, Richard. 1991 "Unusual Magnetotactic Bacteria In Morro Bay" pages 5-2.5-5-2.14 in State of the Bay Proceedings 1992 * #794

Frey, V. 1979 "Impingement Of Fishes And Macroinvertebrates At Pacific Gas And Electric's Morro Bay Power Plant" Unpublished Senior Project. California Polytechnic State University, San Luis Obispo. #722

Friends Of The Estuary At Morro Bay. 1989 "National Estuary Program: Draft Nomination Of Morro Bay" 59 pages #399

Friends Of The Estuary At Morro Bay. 1989 "The Morro Bay Nomination For The National Estuary Program" prepared by Eilleen Bowen, Angela Carpenter, Dave Chipping, Steve Eabry, Holly Frank; Susan Hilinski-Farrel, Connie Harms, Paul Jagger, Linda Joncs, Bud Laurent, Bill Mazzacane, Jean McKown, Don Parham, Phil Persons, Galen Rathbun, Tom Rice, and Karen Worcester. #932

Gallagher, J. 1993 "Late Holocene Depositional History, Sea Level Change And Subsidence Activity Of A Tidal Wetland At Morro Bay, California" [Ph.D. Dissertation] Los Angeles, University of California. #554

Gambs, R. D. 1986 "Status Of Morro Bay Kangaroo Rats On 3 Study Plots At The Bayview Site In 1984 And 1985. Interim Report" U.S.Fish and Wildlife Service, Sacramento, California 29 pages #1514

Garing, Taylor and Assoc., Inc. 1981 "City Of Morro Bay Municipal Water Distribution System (maps)" prepared in 1969 with numerous revisions by City through 1981 #2201

Gerdes, Gene L., Edward Primbs, and Bruce Browning ; Assisted By Clyde S. Edon. 1974 "Natural Resources Of Morro Bay, Their Status And Future" California Department of Fish and Game Coastal Wetland Series #8. 35 pages #585

Gibson, Robert O. 1981 "Cultural Resource Test Program At SLO 978 Morro Bay, San Luis Obispo County, California" Report to U.S.Army Corps of Engineers, Los Angeles District. #1001

Gibson, Robert O. 1991 "The Chumash Of San Luis Obispo County" pages 3-1.1-3-1.8 in State of the Bay Proceedings 1992 * #789

Grabiel, P. O. 1993 "Salt Pan Formation And Development On An Intertidal Delta" [M.A. Thesis] Los Angeles, University of California #1371

Grote, Jeffrey. A. and Tito. Patri. 1975 "A Coastal Watershed Environmental Management System: Morro Bay, California" Prepared for the San Luis Obispo County and Cities Coordinating Council by the Conservation Planning Collaborative, Inc. #588

Haggard, Ken. 1972 "Design Proposal For A State Center For The Study Of Estuarine Ecology In The Morro Bay Area" Senior Project 17 pages #826

Hall, C. A. and L. W. Prior. 1975 "Geologic Map Of The Cayucos-San Luis Obispo Region, San Luis Obispo County, California" U.S.Geological Survey. Miscellaneous Field Studies Map MF-511. #404

Hall, C. A. 1982 "Pre-Monterey Subcrop And Structure Contour Maps, Western San Luis Obispo And Santa Barbara Counties, South Central California" U.S.Geological Survey Map MF-1384. #544

Haltiner, J. and J. Galton. 1987 "Preliminary Analysis Of Sedimentation Processes In Morro Bay" Prepared for the California Coastal Conservancy, February 1987. #591

Haltiner, J. 1988 "Sedimentation Processes In Morro Bay, California" Prepared for Coastal San Luis Resource Conservation District and California Coastal Conservancy by Philip Williams and Associates, San Francisco. 93 pages #1640

Haltiner, J. 1991 "Sedimentation Processes In Morro Bay, California" State of the Bay Conference presentation * #802

Hand, C., and J. Steinberg. 1955 "On The Occurrence Of The Nudibranch Alderia Modesta (loven, 1844) On The Central Californian Coast" The Nautilus 69 pages 22-28. #11

Hardy, Robert. 1991 "Recreational Fishing In Morro Bay" pages 6-2.5-6-2.7 in State of the Bay Proceedings 1992 * #799

Harms, Connie. editor. 1991 "Morro Bay: A Natural Classroom For Teachers, A Curriculum For Teachers" Prepared by The Morro Bay Task Force. #784

Hatai, Kenneth K. 1982 "Morro Bay Area Water Management Plan" California Department of Water Resources, Southern District 66 pages #373

Haydock, C. I. 1960 "A Survey Of Morro Bay Eel Grass, June Thru August 1960" California Department of Fish and Game 5 pages #1641

Hayes, Stephen P. and Peter T. Phillips. 1986 "California Mussel Watch 1984-1985. Annual Report Trace Metals And Synthetic Organic Compounds In Mussels From The Coast, Bays And Estuaries" California Water Quality Control Board Water quality monitoring report 86-3. #654

Hayes, Stephen P. and Peter T. Phillips. 1987 "California Mussel Watch 1985-1986. Marine Water Quality Monitoring Program" California Water Quality Control Board Water quality monitoring report 58 pages #655

Heath, W. P., Jr. 1983 "Traffic Report For Environmental Impact Report For Morro Shores Tract 959" prepared for MDW Associates. (ED 81-50), Appendix A: #1099

Holland, Dan. 1985 "An Ecological And Quantitative Study Of The Western Pond Turtle (clemmys Marmorata) In San Luis Obispo County" [M.A. Thesis] Fresno State University, California #576

Holland, Dan. 1990 "Natural History Of Southwestern Pond Turtles" Presentation to the Central Coast Biological Society, May 10, 1990, San Luis Obispo, California #577

Holland, Dan. 1990 "Unpublished Data On Locality Sitings Of Reptiles And Amphibians In Central Coastal California" Southwestern University of Louisiana. #575

Holland, V. L. and D. Keil. 1986 "Effects Of The Proposed County Service Area 9 Waste Water Treatment Facility On The Vegetation Of The Lower Los Osos Creek Riparian Corridor" Included in: The Morro Group "County Service Area 9 Waste water treatment Environmental Impact Report" Appendix D-4. #408

Holland, V. L. and D. Keil. 1986 "Vegetation Of The Los Osos Baywood Park Area, San Luis Obispo County, California. Impact Assessment" prepared or San Luis Obispo County for County Service Area 9 Wastewater Treatment Facility Environmental Impact Report. #1322

Holland, V. L. and D. Keil. 1986 "Vegetational Survey Of The Twin Bridges Project Site On South Bay Boulevard, Morro Bay, California" Prepared for California Department of Transportation. #1423

Holland, V. L. 1991 "Botanical Survey Of The Proposed AT&T Cable Line From The San Luis Obispo Junction To The Parking Area In Montana De Oro State Park, San Luis Obispo County" Prepared by The Morro Group for San Luis Obispo County. #1321

Horn, M. H. 1980 "Diel And Seasonal Variation In Abundance And Diversity Of Shallow Water Fish Populations In Morro Bay, California" California Department of Fish and Game Bulletin 78(3) pages 759-770 #410

Hutchinson, Elmarie S. Gary Page and Philip E. Persons. 1987 "The Nesting Of Snowy Plovers On Morro Bay Sand Spit During And After The 1987 Maintenance Dredging Of Morro Bay Harbor" Publication of Point Reyes Bird Observatory. 16 pages #936

Hynes, C. D. 1986 "Entomology Survey Report For The Twin Bridges Project Site" Prepared for California Department of Transportation. #1427

Intersea Research Corporation. 1974 "Inventory Of Environmental Factors At Estero And Morro Bay Related To Proposed Offshore Terminal Modifications At The Morro Bay Power Plant" prepared for Pacific Gas and Electric, Department of Engineering Research, 3400 Crow Canyon Road, San Ramon, California, April 17, 1974. #1247

John Carollo Engineers. 1962 "Report On Waste Water Reclamation And Reuse, Morro Bay Area, San Luis Obispo County, California" Berkeley 1 v.: ill., maps, fold. plates ; 28 cm. G4814 J2 #630

John Carollo Engineers. 1973 "Report On Water Supply, City Of Morro Bay, California" Walnut Creek, California. February. #2202

John Carollo Engineers. 1974 "Trunk Sewer Study For The City Of Morro Bay, California, 1974" Walnut Creek, California. August. #2203

John Carollo Engineers. 1975 "Master Water Plan For The City Of Morro Bay, California, 1975" Walnut Creek, California. February. #2204

John Carollo Engineers. 1977 "Morro Bay-Cayucos Wastewater Treatment And Disposal Facilities Draft Environmental Impact Report." Walnut Creek, California. July. #2206

John Carollo Engineers. 1977 "Potential Water Supply Projects, City Of Morro Bay" Walnut Creek, California. April. #2205

John Carollo Engineers. 1978 "Morro Bay Cayucos Wastewater Treatment And Disposal Facilities Draft Environmental Impact Report." Walnut Creek, California. September. #2208

John Carollo Engineers. 1978 "Morro Bay Cayucos Wastewater Treatment And Disposal Facilities Project Report Final Draft No. 2." Walnut Creek, California. May. #2207

John Carollo Engineers. 1978 "Morro Bay Cayucos Wastewater Treatment And Disposal Facilities Project Report Final Draft No. 3." Walnut Creek, California. September. #2209

John Wallace and Associates, Consultants. 1987 "The City Of Morro Bay Storm Drain Master Plan" City of Morro Bay Department of Public Works. #972

Johnson, Joe William. 1945 "Report On Wave Data From Morro Bay" University of California, College of Engineering. HE-116-66 Institute of Engineering Research series ; no. 3, issue no.66. 25.5 X-3 no.66 #631

Josselyn, Michael, Molly Martindale, John Callaway. 1989 "Biological Resources Of Morro Bay As Impacted By Watershed Development In Los Osos And Chorro Creek Watersheds" Prepared for the California Coastal Conservancy by Romberg Tiburon Centers, Center for Environmental Studies, San Francisco State University. QH 5415S3 B5 35 pages * #2234

Junak, Steven A. 1990 "Botanical Survey Of Abandoned Mining Roads, Firebreaks, And Unauthorized Off Road Vehicle Trails With Accelerated Erosion Problems, West Cuesta Ridge Area, Los Padres National Forest, San Luis Obispo County, California Draft Report" Prepared for the U.S.Forest Service, Santa Lucia District, Santa Maria, California. #1325

Kalb, Connie and Collum, Brooks. 1981 "Effects Of Fire On Coastal Scrub Vegetation, Black Hill, Morro Bay State Park" 37 pages #827

Kelly, J. L. and D. W. Behrens. 1982 "Fish Composition Of Tri-net Trawls In Morro Bay" Pacific Gas and Electric Company, Department of Engineering research SH 221.5.M6 K4 * #2284

King, C. 1985 "Morro Bay State Park Exotic Plant Survey" Prepared for the Morro Bay State Park. 13 pages #1643

Kline, K. F. 1970 "Fishes Collected In Morro Bay, California Between January 1968 And December 1969" [senior Thesis] California Polytechnic State University, San Luis Obispo, California 26 pages #1644

Knepher, Tom, compiler. 1991 "State Of The Bay Conference Proceedings" Prepared by the Morro Bay Task Force. 57 pages. #783

Knepher, Tom, compiler. 1991 "State of the Bay columns 1990-1991. " A series of newpaper articles related to Morro Bay and its watershed G4814 N1-3 57 pages * #644

Krystoff-Jones, June M. 1986 "Sediment Analysis At Selected Sites In The Morro Bay Estuary A Measure Of Habitat Suitability For Callianassa Californiensis" For the California Department of Fish and Game, Biological Sciences Department, California Polytechnic State University GC 97.8.M6 * #2252

Ladd, J. L., Hayes, Sp., Martin, M. Stephenson, M. D., Coale, S. L., Linfield. J. and Brown, M. 1984 "California Mussel Watch 1981-1983. Biennial Report Trace Metals And Synthetic Organic Compounds In Mussels From California's Coast, Bays, And Estuaries" California Water Quality Control Board Water quality monitoring report 83-3TS, 81 pages #656

Land Conservancy Of San Luis Obispo County. 1992 "Land Lines, Quarterly, Newsletter" Land Conservancy of San Luis Obispo County, PO Box 12206, San Luis Obispo, California 93406 various dates #832

Land Design Systems. 1981 "Morro Bay Dunes." Upland, California: Land Design Systems, TC 339.M6 * #2262

Laurent, Bud. 1991 "State Of The Bay Welcoming Address" pages 2-1.1-2-1.3 in State of the Bay Proceedings 1992 * #787

Leedshill-Herkenhoff Inc. 1988 "Coastal Streams Diversion And Storage Project, Feasibility Study" Prepared for the Whale Rock Commission and the City of Morro Bay. #974

Lidberg, James. 1991 "Waterfowl Hunting On Morro Bay Traditional Use And Current Controversy" pages 6-1.1-6-1.4 in State of the Bay Proceedings 1992 * #798

Lin, X. 1991 "Bank Collapse Along Wetland Channels, Chorro Delta, California" [M.A. Thesis] Los Angeles, University of California. #1373

Local Agency Formation Commission. 1984 "Sphere Of Influence Study For County Service Area No. 9 (south Bay)" prepared by the San Luis Obispo County Local Agency Formation Commission, July, 1984. #1098

Macintyre, J., S. R. Sparling, M. Faustini, T. L. Richards, R. Nakamura and B. F. Putnam. 1986 "Resource Inventory, Marine Life: Cayucos State Beach, Morro Strand State Beach, Atascadero State Beach, Morro Bay State Park, Montana De Oro State Park" Interagency Agreement Number 4-823-6011, California Department of Parks and Recreation and the Trustees of the California University System. California Polytechnic State University. Biological Sciences Department.110 pages #923

Manolis, T. D. 1977 "California Black Rail Breeding Season Survey In Central California" California Department of Fish and Game Non-game wildlife investigations, Endangered Wildlife Program, 14 pages #424

Marquardt, G. P. 1991 "The Chorro Delta Drainage Network" [M.A. Thesis] Los Angeles, University of California. #1374

Marshall, Bruce D. 1987 "Report On Safety, Maintenance And Ecological Problems Associated With The Morro Bay Harbor Entrance Design" TC 225.M6 M3 * #2242

Martin, M., D. Crane, T. Lew, and W. Seto. 1982 "California Mussel Watch 1980-1981. Part II Synthetic Organic Compounds In Mussels, Mytilus Californianus And M. Edulis From California's Coast, Bays And Estuaries" California Water Quality Control Board Water quality monitoring report 81-11TS 72 pages #661

Matin, A. K. 1982 "Hydrologic Evaluation Of Los Osos Basin, San Luis Obispo County, California:" [M.S. Thesis] CSU Los Angeles, October, 1982. #1101

Meek, R. T. 1945 "Comparison Of Retraction Methods Utilized At Amphibious Training Base At Coronado And Morro Bay. Berkeley, California" Engineering research projects. HE-116-93 University of California, Berkeley. College of Engineering. Fluid Mechanics Division. Institute of Engineering Research series ; no. 3, issue no.93. 25.5 X-3 no.93 #633

Mello, John. J. 1980 "Morro Bay Mudflats, Once Regarded As A Wasteland: It Is A Virtual Food Factory" Outdoor California 41(6) pages 1-4 #1647

Mello, John. J. 1981 "A One Year Survey Of Recreational Clamming On The Morro Bay Mudflats For The Period Of April 1979 To March 1980" [Senior Thesis] California Polytechnic State University, Department of Biological Sciences Project # 81-0340 18 pages #1648

Merriam Planning Associates and Jo Duthie. 1988 "Morro Bay Marina Draft Focused Environmental Impact Report" Prepared for City of Morro Bay Community Development Department. #1555

Meyer, E. W. Bud. 1991 "Plants That Grow In The Tidal Zone Around Morro Bay" pages 5-5.29-5-5.32 in State of the Bay Proceedings 1992 * #797

Moffatt and Nichol, Engineers. 1962 "Morro Bay Harbor Feasibility Study" Expansion of Morro Bay Harbor for pleasure and commercial boating was analyzed by Moffatt and Nichol, Engineers. Dramatic changes were proposed throughout the Bay, including the dredging of most of the South Bay to allow navigation. #1219

Moffatt and Nichol, Engineers. 1962 "Morro Bay Harbor Feasibility Study" Prepared for San Luis Obispo County, California 83 pages * #2228

Mooney, Melissa. 1991 "From Cypress To Sandspit; The Plants And Plant Communities Of The Morro Bay Watershed" pages 5-4.18 5-4.29 in State of the Bay Proceedings 1992 * #796

Morro Bay Task Force. 1990 "Unanswered Questions: Research Needs In The Morro Bay Watershed" Draft. #97o

Mueller, Troye C., Kelly, Lynn, M. 1975 "A Preliminary Study Of The Flora And Fauna Of A Freshwater Pond" California Polytechnic State University Sweet Springs, Los Osos 57 pages #817

Munro. 1957 "Observations Of The Winter Waterfowl Population At Morro Bay, California" The Murrelet 38 pages 9-25 #1500

Nakamura, R. 1986 "Summary Report Of Point Survey Of Twin Bridges Project Site: Tidewater Goby Habitat Analysis" Prepared for California Department of Transportation. #431

National Ocean Survey. 1987 "Navigation Chart Of Estero Bay" Chart No. 18703 * #1559

Neuhauser, Judy. 1991 "Make Way For Ducklings: The Importance Of Habitat Continuity In Riparian Systems" pages 8-2.9-8-2.13 in State of the Bay Proceedings 1992 * #807

Nilmeier, H. P., Morey, Ben F. 1945 "Draft Reconnaissance Report. Memorandum On Trip To Fort Ord And Morro Bay, January 16-21" Berkeley, California: University of California, Department of Engineering. Description: 4 leaves ; 28 cm. IER series ; 3, no.54] Title altered: Wave observation stations-IV. At head of title: HE-116-54 At head of Cover title: Engineering research projects. Water waves, Observations. Institute of Engineering Research series ; no. 3, issue no.54. Call number: 25.5 X-3 no.54 #639

Noda, Edward K., Jen, Yuan. 1975 "Sand Transport Analysis, Morro Bay Final Report" Prepared for the U.S.Army Corps of Engineers, Los Angeles District. Tetra Tech, Incorporated, Pasadena, California 1 v.: ill., maps, fold. plates ; 27 cm. Sedimentation and deposition, Mathematical models. Sand. G4814 K5-2 #640

North, Wheeler J. 1969 "Biological Effects Of A Heated Water Discharge At Morro Bay, California" Aquatic biology, California. Aquatic plants. G4814 J9-1 17 pages #641

Orme, A. R. and Tchakerian, V. P. 1986 "Quaternary Dunes Of The Pacific Coast Of The Californias" Included in: "Aeolian Geomorphology" W.G.Nickling, editor. Allen & Unwin, London. pages 149-175. #548

Orme, A. R. 1990 "The Instability Of Holocene Coastal Dunes: The Case Of The Morro Dunes, California" Included in: "Coastal Dunes: Form and Process" Nordstrom, K.F., Psuty, N.P., and Carter, R.W.G. editors. John Wiley & Sons, New York. pages 315-336. #611

Orme, A. R. 1991 "Evolution Of The Morro Barrier-lagoon System A Synthesis" pages 7-3.39-7-3.48 in State of the Bay Proceedings 1992 * #804

Orme, A. R. 1991 "Wetland Morphology, Hydrodynamics And Sedimentation" Included in: "Wetlands: A Threatened Landscape" M.Williams, editor. Blackwell, Oxford. pages 42-94. #547

Pacific Gas and Electric Company. 1973 "An Evaluation Of The Effect Of Cooling Water Discharges On The Beneficial Uses Of Receiving Waters At Morro Bay Power Plant." San Francisco, California QH 545.H93 E9 * #2301

Parhad-Browne, M. 1981 "Growth Of Crassostrea Gigas In Morro Bay" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 22 pages #1652

Pillsbury, Norman H. 1979 "Erosion Sources In The Morro Bay Watershed" Prepared for Local Coastal Program; San Luis Obispo County Planning Department. March. QE 581.P5 #595

Pillsbury, Norman H. 1979 "Erosion Sources In The Morro Bay Watershed" This study identifies the major sources of erosion in the Morro Bay watershed. Standard Soil Conservation Service methodology was used throughout the analysis. Maps were prepared showing land use, Soil erodibility, rainfall intensity, slopes, vegetal cover, stream order, and transportation facilities. Aerial photos were used to identify and map gullies, landslides, and eroding stream banks. * #1216

Putman, Barry. 1991 "Invertebrates Of Morro Bay" pages 5-3.15-5.3.1 in State of the Bay Proceedings 1992 * #795

Read, Lawrence and Jeffery Odell. 1986 "Alterations In The Dynamics Of Morro Lagoon" Morro Bay Environmental Research Center, QH 541.5.S3 R4 * #2236

Reid, R. 1985 "Brant Geese Hunting On Morro Bay During The 1983 Season" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 13 pages #1654

Reish, D. J. and J. L. Bamard. 1967 "The Benthic Polychaeta And Amphipoda Of Morro Bay" Proceedings U.S. Natural History Museum 120 pages 1-26. #523

Richards, John and Novak, Cathy. 1991 "The Commercial Fishing Industry And Morro Bay" pages 4-1.1 4-1.10 in State of the Bay Proceedings 1992 * #790

Robbins, Scott. 1991 "Are Grazing And Watershed Enhancement Compatible?" pages 8-3.14-8-3.19 in State of the Bay Proceedings 1992 * #808

Roest, A. 1977 "Distribution And Population Estimate Of The Morro Bay Kangaroo Rat, 1977" Report for California Department of Fish and Game, Contract No. S1312, 19 pages #1515

Roest, A. 1982 "Morro Bay Kangaroo Rats" Included in: "CRC Handbook of Census Methods for Terrestrial Vertebrates" D. E. Davis editor. CRC Press. Boca Raton, Florida. #1516

Rote, James. 1991 "The Big Picture, Seeing The Forest And The Trees" pages 2-2.4-2-2.10 in State of the Bay Proceedings 1992 * #788

Ruppert, Ron. 1991 "Birds Of The Morro Bay Ecosystem" pages 5 5-1.4 in State of the Bay Proceedings 1992 * #793

Russel, Barbara, Richards, John. editors. 1992 "Morro Bay: State Of The Bay Conference Proceedings, October 12, 1991" Prepared by the Morro Bay Task Force. 225 pages #785

Saint-Amour, M. H. 1983 "Age Distribution Of Brant At Morro Bay, California" [Senior Thesis] California Polytechnic State University, San Luis Obispo, California 14 pages #1655

Salopek, Paul, and Sharon Cove. 1980 "Ecological Survey Of Morro Bay: Contrasting Environments Within The Morro Bay Wetlands System" QH 105.C2 S3 * #2318

San Luis Obispo County Engineering Department. 1987 "Flood Plain Assessment: A Study Of Floodplain Impacts Of Proposed Bridge Construction On South Bay Boulevard In The City Of Morro Bay, California" 7 pages #451

San Luis Obispo County Planning Department. 1972 "A Specific Plan For The Preservation Of The Morros" San Luis Obispo, California: QE 90.S18 S3 51 pages #818

San Luis Obispo County. 1962 "Morro Bay Harbor General Plan" San Luis Obispo County Planning Department. San Luis Obispo, California: HT 394.S3.M6 * #2337

San Luis Obispo County. 1974 "Draft Environmental Impact Report For Morro Shores Mobile Home Park Expansion" Prepared by Environmental Impact Reports, Inc. #772

San Luis Obispo County. 1985 "Environmental Impact Report And Addendum For Holland Development Plan And Tract Map" Prepared by McClelland Engineers. #771

San Luis Obispo County. 1985 "Supplemental Environmental Impact Report For Proposed Cabrillo Estates Subdivision, Tentative Tract 308" HT 393.C3 C3 * #2346

San Luis Obispo County. 1988 "Draft Environmental Impact Report For Twin Bridges Replacement Project" Prepared by Westec Services, Inc. #770

San Luis Obispo County. 1990 "Proposal To Extend The Morro Bay Site Designation Candidacy To Include Outer Waters Between Mill Creek, Monterey County, California And The Southern Flank Of Point Sal," QH 91.75.C2 P7 * #2323

Schubert, Steve. 1977 "A Study Of White Pelicans Wintering In San Luis Obispo" California Polytechnic State University 32 pages #819

Sharpe, Clifford A. 1974 "Shellfish And Water Quality Study, Morro Bay" California Department Of Health Services Sanitary Engineering Section #774

Showers, M. A. T. 1986 "Plant Life Of Morro Bay State Park" Included in: "Resource inventory of Morro Bay State Park" California Department of Parks and Recreation, Report D-2120R. #1656

Snider, W. M. 1974 "A Survey Of Barriers To Fish Migration, Chorro Creek, San Luis Obispo County" California Department of Fish and Game. #460

Soil Conservation Service. 1989 "Morro Bay Watershed Enchancement Plan, San Luis Obispo County, California" sponsored by Coastal San Luis Resource Conservation District, California Coastal Conservancy QH 541.5.M3 E5 * #2314

Soil Conservation Service. 1989 "Morro Bay Watershed Erosion And Sediment Study" Prepared for the Coastal San Luis Resource Conservation District and California Coastal Conservancy. QE 581.E7 51 pages * #615

Squyres, Drew. 1991 "Bay Water Through The Power Plant" pages 4-3.15-4-3.2 in State of the Bay Proceedings 1992 * #792

Stagver, Waive. 1974 "Conspicuous Summer And Fall Flora Of The Sand Spit, Morro Bay State Park" California Polytechnic State University 29 pages #820

State Lands Commission. 1966 "Review Of Morro Bay Grant" prepared for F.J. Hortig, executive officer, State Lands Commission, State of California; R.S. Golden KFC 809.M6 A82 * #2254

Steitz, C. E. 1975 "Angler Use And Catch Composition In The Vicinity Of The Discharge Of Morro Bay Power Plant" Pacific Gas and Electric Company, Department of Engineering Research ; QH 545.H93 S7 * #2300

Steven P. French, Raymond K. Belnap. 1990 "Countywide Settlement Pattern Strategy, San Luis Obispo County: Phase 1 Report" by the Design Institute, California Polytechnic State University, San Luis Obispo HD 1390.C6 * #2273

Stewart, G. R., and A. L. Roest. 1960 "Distribution And Habits Of Kangaroo Rats At Morro Bay" Journal Mammal. 41(1) pages 126-129. #1684

Stratton, J. T. 1868 "Map Of Subdivision Of The Ranchos Canada De Los Osos And La Laguna, San Luis Obispo County" Unpublished map on file with San Luis Obispo County. #1159

Strnad, Les. 1991 "Coastal Zone Management In The Morro Bay Region-a Watershed Management Approach" pages 9-3.17-9-3.21 in State of the Bay Proceedings 1992 * #811

Stump, R. S. 1945 "Comparison Of Data From Morro Bay Observation Stations. Comparison of wave data from Estero Bay observation stations. HE-116-75 Ocean waves, Observations. Estero Bay California" University of California, Berkeley. College of Engineering. Fluid Mechanics Division. Comparison of wave data from Estero Bay observation stations. Institute of Engineering Research series ; no. 3, issue no.75.25.5 X-3 no.75 #645

Stump, R. S. 1945 "Wave Decay Graph, Morro Bay To Fort Ord And Coronado" [2] leaves: ill. ; 28 cm. IER series ; 3, no.77] Cover title altered: "Alteration of Estero Bay decay graph for use at Ft. Ord and Coronodo. HE-116-77 Ocean waves, Forecasting" University of California, Berkeley. College of Engineering. Fluid Mechanics Division. Institute of Engineering Research series ; no. 3, issue no.77. 25.5 X-3 no.77 #646

Swift, C. C., J. L. Nelson, C. Maslow, and T. Stein. 1989 "Biology And Distribution Of The Tidewater Goby, Eucyclogobius Newberryi (pisces: Gobiidae) Of California" Natural History Museum of Los Angeles County. Contributions in Science, Number 404, pages 1-19. #464

Tartaglia, J. 1973 "Chorro Creek Stream Survey Report" California Department of Fish and Game. #465

Tekmarine Inc. 1988 "Morro Bay, California, Hydrographic Survey Investigation Report" prepared for U.S.Army Corps of Engineers, Los Angeles District, Contract No. DAWC09-87-00024. #1264

Tetra Tech. 1975 "Sand Transport Analysis, Morro Bay" Under contract to the U.S.Army Corps of Engineers, Tetra Tech prepared the most comprehensive analysis of the total Morro Bay sediment budget available. The purpose of the study was to evaluate the relative contribution of sediment from littoral transport, windblown sand, and creek transport to the total amount of sediment which must be dredged from the entrance and harbor channels. * #1221

Tetra Tech. 1989 "Preliminary Design And Feasibility Study, The Inn At Morro Bay Marina. Morro Bay. California" Prepared for J.H. Edwards Co., TC-3806. #1569

Tetra Tech. 1989 "Supplemental Report, Field Studies For The Inn At Morro Bay Marina. Morro Bay. California" Prepared for J.H. Edwards Co. #1568

Texaco, Inc. 1983 "Construction Of An Artificial Fishing Reef In Estero Bay" Feasibility Study Prepared by HDR Systems. #775

The Morro Group. 1986 "Draft Environmental Impact Report, County Service Area 9, Wastewater Treatment Facilities, Los Osos, Baywood Park, And Cuesta-by-the-Sea, San Luis Obispo County, California" prepared for San Luis Obispo County HT 393.C3 L6 #1157

The Morro Group. 1986 "Geological And Geophysical Investigations Of Proposed Disposal Site 6 And Conceptual Infiltration Model, County Service Area 9 Wastewater Treatment Facilities" Prepared for the County of San Luis Obispo, January 9, 1986. #425

The Morro Group. 1987 "Final Environmental Impact Report, County Service Area 9, Wastewater Treatment Facilities" Prepared for the County of San Luis Obispo. #983

The Morro Group. 1989 "Supplemental Environmental Impact Report, County Service Area 9 Wastewater Treatment Facilities" Prepared for the County of San Luis Obispo. #427

Thomas, Michael. 1991 "Competition In The Morro Bay Watershed-whose Interests Will Prevail?" pages 9-1.1-9-1.6 in State of the Bay Proceedings 1992 * #809

Thor, Devin. R. 1987 "Bathymetry Survey And Surface Sediment Study: Morro Bay, California" Prepared for Philip Williams and Associates for the Morro Bay Enhancement Study. October. #614

Thorstrum, Lynda J. 1970 "A.B. Spooner 1824-1877" [Senior Thesis] California Polytechnic State University, San Luis Obispo. Based on the diaries of A.B. Spooner loaned by Mrs. Carleton Spooner. #1680

Toyoshima, J. L. 1983 "Small Mammal Population In A Coastal Sage Scrub Community" M. S. Thesis, California Polytechnic State University, San Luis Obispo, 81 pages #1518

U. S. Army Corps Of Engineers. 1941 "Report Of The Board Of Engineers For Rivers And Harbors On Morro Bay" California Acting on a request by the U.S. Congress, the U.S. Army Corps of Engineers investigated the feasibility of constructing harbor improvements in Morro Bay. They recommended improvement of the entrance channel and dredging in the inner Bay. #1213

U. S. Army Corps Of Engineers. 1974 "Final Environmental Statement, Operation And Maintenance Of Morro Bay Harbor" Los Angeles District #1026

U. S. Army Corps Of Engineers. 1976 "Design Deficiency Report On Morro Bay Harbor" Los Angeles District #?

U. S. Army Corps Of Engineers. 1976 "Environmental Impact Report On Maintenance Dredging Operations" The U.S.Army Corps of Engineers has performed maintenance dredging in the entrance channel and harbor channels on a regular basis since 1949. It is interesting to note that one of the criticisms of the 1974 Environmental Impact Report concerned the lack of information on circulation and sediment transport both within the Bay and in the near shore area of soil disposal. #1222

U. S. Army Corps Of Engineers. 1984 "Morro Bay Harbor Maintenance Dredging, Geotechnical Report" Los Angeles District #903

U. S. Army Corps Of Engineers. 1986 "Environmental Impact Report On Maintenance Dredging Operations In Morro Bay" Prepared by District Office. #600

U. S. Army Corps Of Engineers. 1986 "Morro Bay Harbor Dredging Sand Trap Area, Geotechnical Report" Los Angeles District #904

U. S. Army Corps Of Engineers. 1986 "Unpublished Data On Historical Dredging" prepared by the Los Angeles office. #603

U. S. Army Corps Of Engineers. 1987 "Comprehensive Condition Survey, North And South Breakwaters, Morro Bay Harbor, San Luis Obispo County, California" prepared by Los Angeles District. Includes Side scan sonar investigation of two breakwaters at Morro Bay, California by GEOFON, May 1, 1985. TC 22-5.6 C6 * #905

U. S. Army Corps Of Engineers. 1987 "Morro Bay Harbor Draft Reconnaissance Report" Draft reconnaissance report. G4814 M7-6 #636

U. S. Army Corps Of Engineers. 1988 "Reconnaissance Report, Morro Bay Harbor, San Luis Obispo County, California" Los Angeles District. 41 pages #985

U. S. Army Corps Of Engineers. 1990 "Draft Supplemental Environmental Assessment: Morro Bay Harbor Maintenance Dredging, San Luis Obispo County," prepared by the Los Angeles District. TC 187.D7 * #2240

U. S. Army Corps Of Engineers. 1991 "Morro Bay Harbor Draft Feasibility Report: Main Report" Los Angeles District. Volume I, environmental assessment Prior Corps of Engineers reports - p. II-14 TC 225.M6 M62 * #2259

U. S. Army Corps Of Engineers. 1991 "Morro Bay Harbor Feasibility Study: Main Report" Los Angeles District. #986

U. S. Army Corps Of Engineers. 1991 "Morro Bay Harbor Feasibility Study: Public Meeting, Morro Bay, Ca, May 8" Los Angeles District. Los Angeles, CA: TC 225.M6 M622 * #2243

U. S. Army. 1945 "History Of The United States Pacific Fleet Amphibious Training Base: Morro Bay, California, From 16 November 1941" United States Navy. Amphibious Training Base., Morro Bay VA 70.M6 H5 * #2269

U. S. Coast and Geodetic Survey. 1884 "Hydrographic Surveys 1607-a, 4044, And 5751, Morro Bay, Estero Bay, California" obtainable from State Lands Commission, Sacramento, California. #604

U. S. Congress, Committee On Rivers and Harbors. 1941 "Morro Bay, California" [Washington: GPO, 1941.]: fold. maps ; 23 cm. 77th Cong., 1st Sess., House Doc no.283. U.S.War Department U.S.Army. Corps of Engineers. G4814 Gl 19 pages #648

U. S. Federal Insurance Administration. 1979 "Flood Insurance Study, City Of Morro Bay, California, San Luis Obispo County" U.S.Department of Housing and Urban Development, Federal Insurance Administration. Govt Doc No.: HH lO.9:M 83/7 GPO Item No.: 594-C-5 14 pages #649

U. S. Fish and Wildlife Service. 1982 "Morro Bay Kangaroo Rat Recovery Plan" U.S.Fish and Wildlife Reference Service. Rockville Md. 69 pages #1115

U. S. Fish and Wildlife Service. 1982 "Recovery Plan For Morro Bay Kangaroo Rat (dipodomys Heermanni Morroensis)" Portland, OR. * #1576

Vilkitis, J. R. and D. R. Woodley. 1981 "Resource Allocation Issues Associated With Maintaining Instream Flow From Waste Water" Paper presented at the California Riparian Systems Conference University of California at Davis. Sept. 17-19, 1981. #473

Warden, Murray L. 1972 "General Plan For Future Use Of Granted Lands City Of Morro Bay, California" KFC 809.M6 A84 * #2255

Warden, Murray L. 1972 "Land Use And Development Report, Granted Tide And Submerged Lands: City Of Morro Bay, California" KFC 809.M6 A86 * #2256

Wells, P. V. 1962 "Vegetation In Relation To Geological Substratum And Fire In The San Luis Obispo Quadrangle, California" Ecological Monographs 32(1) pages 79-103. #1333

Wells, Patrick. 1989 "Unpublished Water Quality Data From Morro Bay. California" Department of Health Services. San Luis Obispo, California. #1579

Westec Services, Inc. 1988 "Twin Bridges Replacement Project: Draft Environmental Impact Statement, Report And 4(f) Evaluation" Prepared for County of San Luis Obispo. #943

Westec Services, Inc. 1989 "Twin Bridges Replacement Project: Final Environmental Impact Statement, Report And 4(f) Evaluation" Prepared for County of San Luis Obispo. * #990

Wiegel, Robert L., J. Johnson, and U. S. Army Corps Of Engineers. 1967 "Tidal Prism And Entrance Channel Area Data For Morro Bay" This is a collection of unpublished data available in the Water Resources Archives at U.C. Berkeley. It includes data collected by the U.S.Army Corps of Engineers and Professors J. Johnson and R. Wiegel at UC Berkeley on the tidal prism and entrance channel areas. The mean tidal prism (volume of water exchanged between MLLW and MHHW) was estimated at 3.83 x 108 cubic feet, and the entrance channel cross section (area below MSL) was estimated at 8, 800 square feet. The tidal prism was estimated using a 1946 Survey map planimetered at 2 ft. contour intervals. 45 pages #1218

Wiegel, Robert L., Johnson, J., and U. S. Army Corps Of Engineers. 1967 "Tidal Prism And Entrance Channel Area Data For Morro Bay" Unpublished data available in the Water Resources Archives, U.C. Berkeley. 45 pages #608

Wiegel, Robert L. 1967 "An Ocean Engineering Study Of Morro Bay, California" This report presents a thorough history of the changes to the harbor between the 1870's and 1940's, interspersed with insightful comments. It represents a useful resource on available maps and photographs from this period. It does not contain any detailed or quantitative analysis of changes or processes outside of the entrance area. 45 pages #1217

Wiegel, Robert L. 1967 "Correspondence, Photos, Maps: Background Materials For Report" Ocean engineering study of Morro Bay, California 2 folders #650

Wieman, Harold. 1991 "Estuary A Natural Wonderland" A slonha publication Morro Bay, California. Estuarine ecology, 84 N1-5 49 pages #652

Williams, Bill and John Richards. 1991 "Oyster Culture In Morro Bay" pages 4-2.11-4-2.14 in State of the Bay Proceedings 1992 * #791

Worcester, Karen. 1991 "The Aquatic Inhabitants Of Chorro And Los Osos Creeks: Their Habitat Needs And Status" pages 8-1.1-8-1.8. in State of the Bay Proceedings 1992 * #806

Wyman, V. L. 1979 "Morro Bay Power Plant, Units 1-4 Intake Current Velocity Studies" Pacific Gas and Electric Co., Department of Engineering Research, DER Report 420-79.109. #754

Yates, E. B., and John H. Wiese. 1988 "Hydrogeology And Water Resources Of The Los Osos Valley Ground Water Basin, San Luis Obispo County, California" U.S.Geological Survey Water Resources Investigations Report 88-4081. 112 pages GB 1025.C2 Y38 * #991

APPENDIX

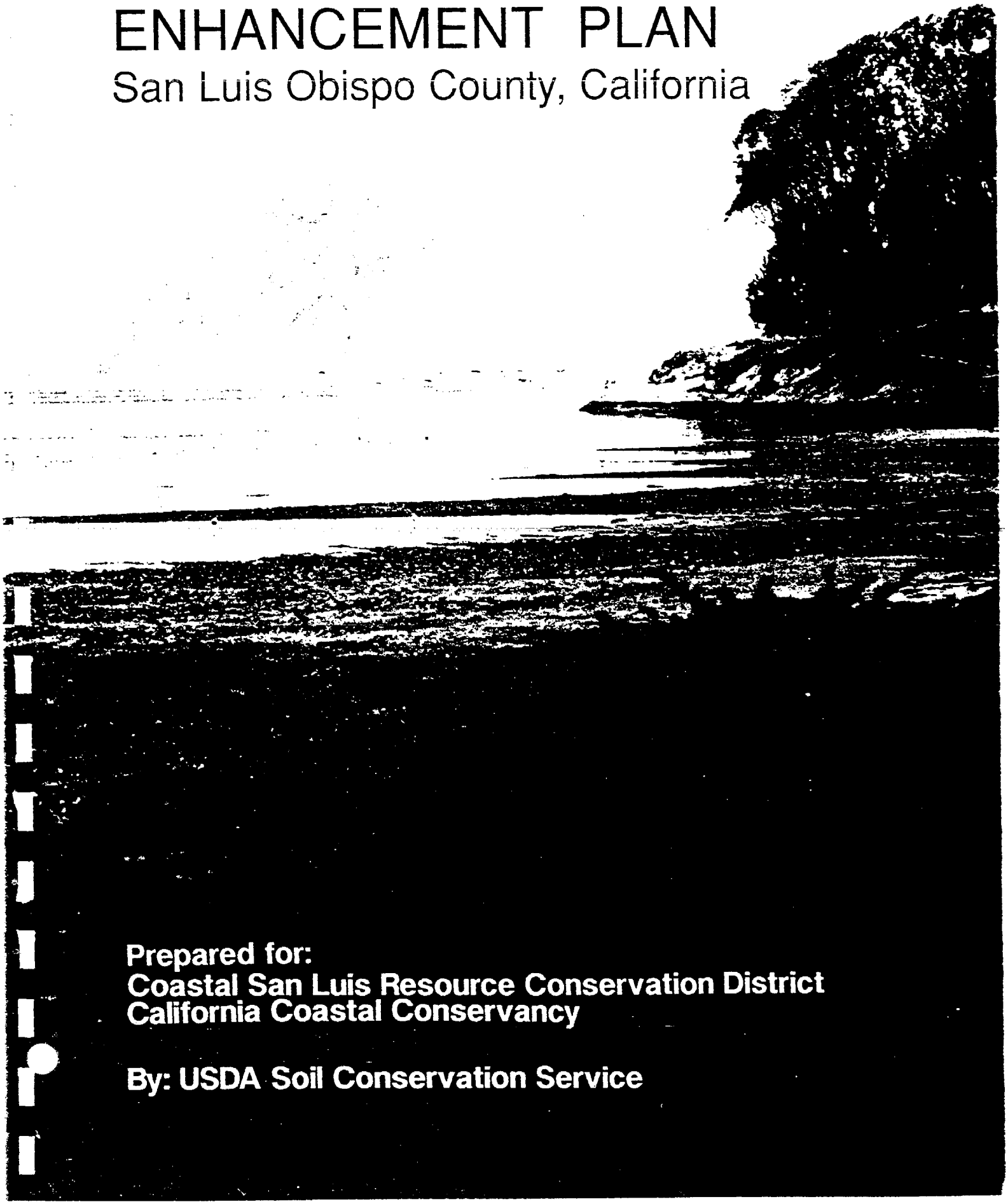
3

ENHANCEMENT PLAN

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

MORRO BAY WATERSHED ENHANCEMENT PLAN

San Luis Obispo County, California



Prepared for:
Coastal San Luis Resource Conservation District
California Coastal Conservancy

By: USDA Soil Conservation Service

ENHANCEMENT PLAN

MORRO BAY WATERSHED

San Luis Obispo County, California

Sponsored By

Coastal San Luis Resource Conservation District
California Coastal Conservancy

Prepared By

U.S. Department of Agriculture,
Soil Conservation Service
Davis, California

September, 1989

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

PREFACE

In August 1987, at the request of the Coastal San Luis Resource Conservation District, the Soil Conservation Service through a grant from the California Coastal Conservancy was requested to provide technical assistance to develop a plan addressing erosion control for the Morro Bay Watershed in San Luis Obispo County.

To develop the plan, an erosion and sediment study was conducted in the watershed. Critically eroding areas were identified and treatment measures were developed to reduce erosion. These were evaluated and a recommended plan was formulated.

Results of these studies were presented in two reports. The first of the two reports entitled "Erosion and Sediment Study in Morro Bay Watershed" was directed to the more technically oriented reader whose interests center in the methodologies used in estimating erosion rates, sediment delivery ratios, and erosion reduction potential. This more technical report also provides a summary of alternative treatment measures that were examined, their costs, and one possible method of implementing the recommended solution.

The following report is directed to the reader desiring a more detailed explanation of the overall planning process with less discussion of the technical methodologies used in developing data. As such, this document stresses the watershed setting, watershed problems, formulation of alternative plans, and a discussion of one method of implementing the recommended plan. It also addresses some of the impacts of installing the recommended plan and describes the level of public participation involved throughout the study.

While every effort was made to have each of the two reports serve as separate entities it is recommended that both documents be read if the reader seeks a comprehensive understanding and explanation of the entire study.

SUMMARY

The "Morro Bay Watershed Enhancement Plan" identifies and discusses proposed land treatment and structural measures to reduce sediment deposition as well as their relative economic feasibility and local acceptability. Selected measures were assessed on the basis of their cost-effectiveness and technical adequacy in reducing sediment yield. Eight groups of measures were evaluated. These included measures for roads, brushland, gully control, riparian management, rangeland, small pastures, conservation cropping, and urban areas. Sediment control structures were also evaluated.

The most cost-effective measures were then formulated into three alternative plans. Each alternative plan, consisting of combinations of economically feasible measures, was further evaluated to determine economic and technical benefits. Alternative I includes the most cost-effective land treatment measures to reduce soil erosion. Alternative II includes the most cost-effective sediment control structures. Alternative III, the recommended plan, includes a combination of the first two alternatives. Costs, installation schedule, some environmental impacts, and responsibilities related to the implementation of the Recommended Plan are discussed.

1. INTRODUCTION

Morro Bay is a rich biological resource on the Central Coast of California in San Luis Obispo County. Recent data indicate that sediment deposition in the bay will result in its loss as a salt water estuary within 300 years. The purpose of the Morro Bay Watershed Enhancement Plan is to identify economically feasible and environmentally accepted measures to reduce sediment deposition in Morro Bay. This report describes watershed erosion problems, resources, formulation of the recommended plan, and some potential environmental impacts. Alternative solutions to reduce sediment yield to Morro Bay from sheet and rill erosion resulting from intensive land use and streambank erosion from unstable creek banks include a selection of different treatments rated on their erosion reduction potential. Twenty-three conservation measures were evaluated for roads, brushland, gully control, riparian management, rangeland, small pastures, conservation cropping, and urban areas. Trap efficiency, cost, and life expectancy were also examined for sediment control structures in the watershed. The Recommended Plan includes combinations of 14 conservation measures and two sediment control structures all of which were evaluated on the basis of cost per ton of sediment reduced by each measure or combination of measures. The Recommended Plan combines rural and urban land treatment with sediment control structures to reduce the average amount of sediment by an estimated 47 percent and provides the greatest reduction of the clay fraction from all erosion sources to help prolong the life of the estuary system. Implementation of the plan will require funding for design and construction of the sediment basins, land treatment measures, and technical assistance, using cost-share funds where appropriate.

The plan has been developed at the request of the Coastal San Luis Resource Conservation District, through a grant from the Coastal Conservancy to provide erosion control for the Morro Bay Watershed. The sponsors requested technical assistance during August, 1987 through a joint agreement with the Soil Conservation Service (SCS) under the authority of the Soil Conservation Act of 1935 (Public Law 74-46).

The SCS provided technical assistance in the development of the plan, and other federal, state, and local agencies assisted in the planning process.

2. PROJECT SETTING

2.1 Location

The Morro Bay Watershed project area is East of Morro Bay, which is located on California's Central Coast, 237 miles south of San Francisco and 11 miles northwest of San Luis Obispo (Figure 1). The total drainage basin of the Morro Bay Watershed is estimated to be 48,450 acres. The Bay is approximately four miles long and one and three quarters miles at its maximum width. The central portion of the Bay encompasses the delta of Chorro and Los Osos Creeks. The salt marsh established on the delta is approximately 400 acres in size and is of considerable biological interest.

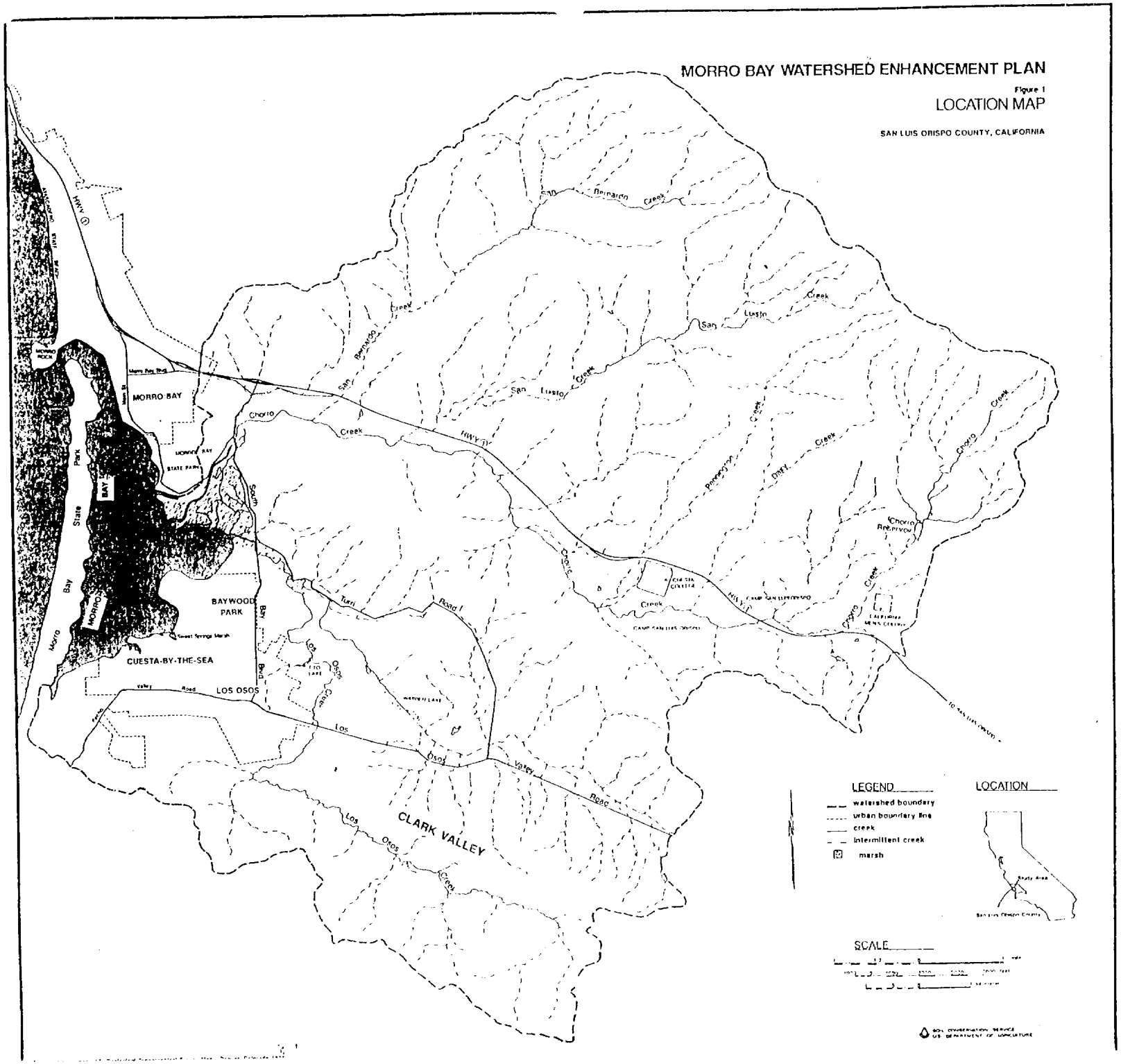
2.2 Climate

The watershed is characterized by a Mediterranean climate of cool, wet winters and warm, dry summers. Mean air temperatures range from lows around 45^{o}F in January to highs of 75^{o}F in October. Ninety five percent of the total annual precipitation falls between November and April with 18 inches being recorded as a 23-year average in the watershed. The wettest year on record in the area was 1969 when 38.74 inches of precipitation were recorded in Los Osos (USDA/SCS Soil Survey, 1981). Prevailing winds are northwest averaging 15 to 20 miles per hour.

2.3 Geology

The underlying bedrock in the watershed is intensely folded, fractured, and faulted. The watershed is underlain by a mixture of igneous, metamorphic, and sedimentary rocks, which are less than 200 million years old. Earthquake activity or intense rainstorms greatly increase landslide potential and severity in sensitive areas. Examples in the Morro Bay Watershed of such areas include debris landslides, soil creep, and large slumps. Active slumps or creep areas may be covered with grass sod and will move as a unit. Sediment deposition from these and other sources impact the Chorro/Los Osos Delta and the lower channel reaches of Chorro and Los Osos Creeks. The loss of Bay volume is also accelerated by the eastward shifting of the spit (Morro Bay State Park, Figure 1).

Morro Bay was formed in the last 10,000 to 15,000 years by the submergence of the river mouth at the confluence of Chorro and Los Osos Creeks. This submergence was a result of the post-glacial rise in sea level of several hundred feet (Haltiner, 1988). Subsequent littoral transport created the spit to the west of the Bay.


MORRO BAY WATERSHED ENHANCEMENT PLAN
Figure 1
LOCATION MAP
SAN LUIS OBISPO COUNTY, CALIFORNIA
MORRO BAY
BAYWOOD PARK
CUESTA-BY-THE-SEA
LOS OSOS
CLARK VALLEY
Morro Bay State Park
Chorro Creek
San Bernardo Creek
San Luisito Creek
Pennington Creek
Dairy Creek
Los Osos Creek
Turri Road
Los Osos Valley Road
Highway 1
Highway 101
Chorro Reservoir
Camp San Luis Obispo
Sweet Springs Marsh
Morro Bay Blvd
South Bay Blvd
LEGEND
watershed boundary
urban boundary line
creek
intermittent creek
marsh
LOCATION
Study Area
SCALE
SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE

2.4 Land Use

Rangeland (grassland) comprises approximately 60 percent of the watershed study area (Figure 2, Table 1). Livestock operations are principally cow-calf enterprises supported by highly productive grasslands. Emphasis on range beef production and economic return brought steeper and more marginal areas of rangeland into use.

Cropland is farmed using a grain-garbanzo bean rotation with the grain stubble used by grazing livestock. Snow peas and vegetables are grown where irrigation water is available and winter temperatures permit active growth.

State and city parks and beaches are present in the area and include over 2,250 acres within the city limits of Morro Bay. Morro Bay State Park maintains 130 camp sites and 18 full trailer hookups. There are 11 city parks within the City of Morro Bay. Montana De Oro State Park is located about 11 miles south of Morro Bay city along 1 1/2 miles of coastline, and includes 6,800 acres of beach, rugged cliffs, and promontories rising to 200 feet above sea level.

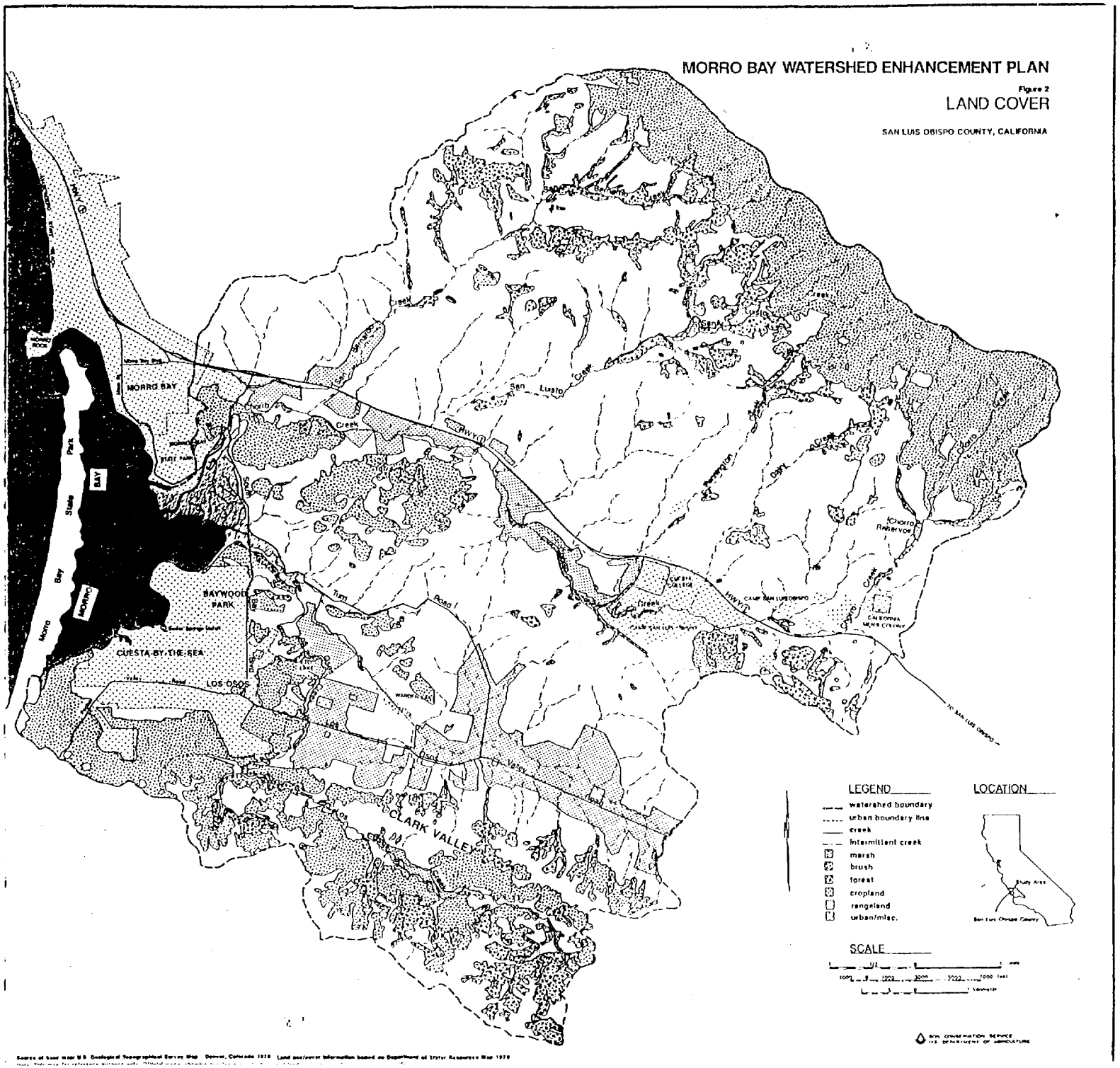
Urban development (Figure 3) in the watershed area is represented by the city of Morro Bay (population 9,870) and the unincorporated communities of Baywood Park, Los Osos, and Cuesta by-the-Sea (population 15,000+). Within the city limits of Morro Bay there are 156 acres zoned for light industry, all of which are currently in use. Urban development is controlled by a water shortage problem.

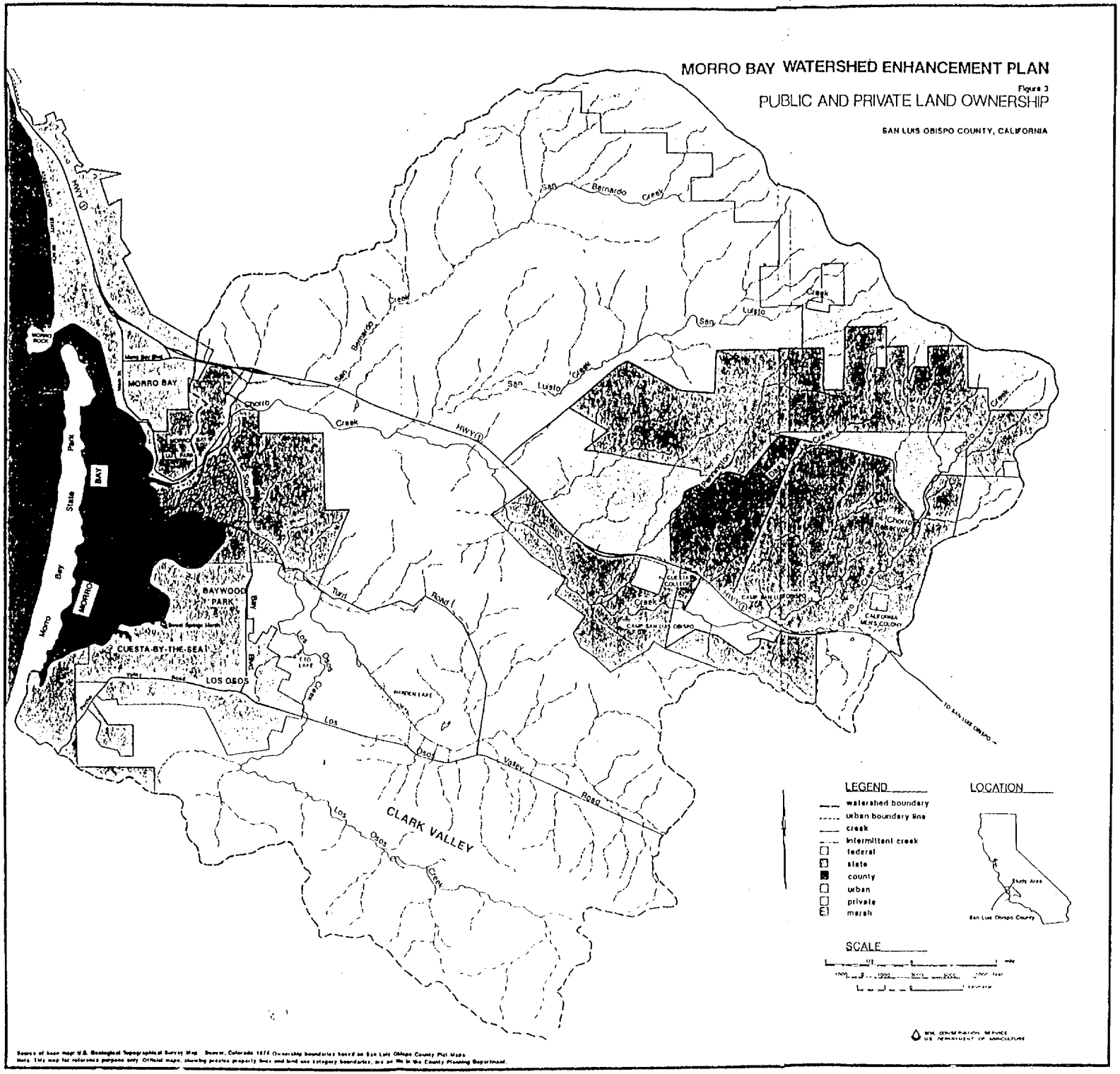
Table 1. LAND USE AND VEGETATION TYPES

Vegetative Cover Type	Chorro Creek (acres)	Los Osos Creek (acres)	Watershed Total (acres)	Percent of Watershed
Truck Crops	238	422	660	1
Field Crops	300	616	916	2
Grain Crops	1,233	340	1,573	3
Woodland	2,155	938	3,093	7
Urban 1/	300	3,389	3,389	8
Brushland	5,685	2,634	8,319	19
Rangeland	17,568	8,594	26,162	60
TOTAL	27,179	16,933	44,112	100

Based on 1978 DWR Data.

1/ CAMP San Luis Obispo, Cuesta College, and California Men's Colony.


MORRO BAY WATERSHED ENHANCEMENT PLAN
Figure 2
LAND COVER
SAN LUIS OBISPO COUNTY, CALIFORNIA
MORRO BAY
Morro Bay State Park
MORRO BAY
CUESTA-BY-THE-SEA
BAYWOOD PARK
LOS OSOS
CLARK VALLEY
San Luisito Creek
Chorro Reservoir
CAMP SAN LUIS OBISPO
CALIFORNIA MENS COLONY
Hwy 1
Hwy 101
LEGEND
watershed boundary
urban boundary line
creek
intermittent creek
marsh
brush
forest
cropland
rangeland
urban/misc.
LOCATION
SCALE


MORRO BAY WATERSHED ENHANCEMENT PLAN
Figure 3
PUBLIC AND PRIVATE LAND OWNERSHIP
SAN LUIS OBISPO COUNTY, CALIFORNIA
MORRO BAY
CUESTA-BY-THE-SEA
BAYWOOD PARK
LOS OSOS
CLARK VALLEY
Morro Bay State Park
Morro Bay
Morro Rock
San Bernardo Creek
San Luisito Creek
Chorro Creek
Los Osos Creek
Los Osos Valley Road
Turri Road
Highway 1
Highway 101
California Men's Colony
Camp San Luis Obispo
Cal Poly College Farm
To San Luis Obispo
LEGEND
watershed boundary
urban boundary line
creek
intermittent creek
federal
state
county
urban
private
marsh
LOCATION
San Luis Obispo County
SCALE

2.5 Socio-Economic

The communities and social groups within or adjacent to the watershed are diverse and dynamic. The area is expected to experience increased growth demands well into the next century including increased demands for wildland recreation. By 2020, the population of San Luis Obispo County is projected to increase 123 percent from present levels of about 200,000 (USDA/Forest Service, 1988). Age groups over 35 years including retirees are expected to increase at various rates (California Department of Recreation, 1982). A gradual shift toward increased demands to manage resources for sustained utilization and recreation will probably occur as a result (Cebula, 1974). Population projections are based on a steady rate of growth which could be impacted by growth associated problems with wastewater treatment or water shortages.

Taxable retail sales in the City of Morro Bay currently exceed 62 million dollars annually. Assessed property valuation is 548 million dollars (1987). Wages paid in the County are generally 30 to 50 percent less than in major metropolitan areas. The mostly retail and small business labor pool is drawn from local sources as well as from residents of the City of San Luis Obispo, students attending Cuesta College, and California Polytechnic State University who move to the area to attend these two schools.

3. PROBLEM STATEMENT

Data on coastal estuary systems indicate a typical life expectancy for the existence of an open water coastal estuary is between 10,000 to 15,000 years (Haltiner, 1988). The open water areas of Morro Bay would have continued to exist for an estimated 2,000 to 3,000 years if conditions which were present in 1700 AD had not been changed by the watershed responses to land use changes associated with the population increase.

Historical Perspective

The first significant land use change which occurred was the introduction of domesticated grazing animals into the watershed. Hillsides and valley bottom were cleared for wood and agriculture. As the population increased, more clearing for grazing, farming and urban uses occurred in the watershed.

During the 1800's a drought and related economic changes established the present ownership patterns in most of the watershed. The valley floor was cleared for dairies and crop production. Roads were built, creeks relocated, and new crops were introduced into the watershed. Communities were created by subdividing areas into townsites. The problem of periodic flooding of agricultural land was solved by putting levees along the creeks.

These changes in land use caused an increase in the amount of runoff from the watershed. Creeks responded to changes in runoff volumes, relocations, and loss of overbank flow areas, by becoming deeper and wider.

Problem

There are few visible signs of erosion and sediment problems in the Morro Bay Watershed. Few gullies are visible from public roads. Agricultural practices and rainfall patterns do not present visible evidence of sheet and rill erosion on most cropland. The rates of erosion, with the exception of road and streambank erosion are usually too small to be perceived by the untrained eye and are not excessive for most individual sites. It is, however, the cumulative effect from all 43,000 acres in the study area which impact the Bay.

The sediment delivered to Morro Bay from the watershed is believed to have generally increased since 1700 AD. This increase is probably due to: 1) changes in land use resulting in more sediment becoming available for movement into the Bay, and 2) other depositional areas in the valley floor no longer being available for sediment deposition due to increased creek depth or levee development. The rate of sediment delivery to Morro Bay has been estimated to have been approximately 45,000 cubic yards per year between 1890 and 1935.

The sediment rate between 1935 and 1986 decreased and was estimated to have been approximately 37,000 cubic yards per year (Haltiner, 1988). These estimates are from the comparison of four bathmetric surveys done since the 1890's. The reduction in the rate of sediment delivered between the two periods may be due to changes in agricultural methods, improved management, and the creek system reaching quasi-equilibrium to changes in the watershed.

The Erosion and Sediment Study, Morro Bay Watershed (USDA, SCS, 1989) identified sources of sediment to the Bay. This sediment begins either as sheet and rill erosion from brushland, woodland, cropland, rangeland, and urbanland or this sediment is detached from gullies, roadbanks, and streambanks. All of this sediment does not reach the Bay. The percentage delivered varies for each point of origin and is generalized in a sediment delivery ratio (SDR) from various sources. The present rate of sediment production is estimated to be 50 percent greater than during the 1700's. The volume of sediment delivered from each acre is small but the cumulative effect contributes to the overall problem. The estimated quantity of sediment delivered to Morro Bay is currently 45,500 tons per year. This is an average value, in reality pulses of sediment are delivered by large storm events.

The increase in sediment delivery to Morro Bay from natural and man-affected sources has increased the rate of change of the open water coastal estuary to a salt marsh/fresh water wetland and upland habitat. Should present conditions continue, the presence of open water in the non-dredged areas of Morro Bay will end in an estimated 300 years (Haltiner, 1988).

The reduction in the volume of sediment reaching Morro Bay is necessary because the fish and wildlife habitat in the Bay is a sensitive coastal resource. There are three main zones in the Bay; deep (below -2.5 feet National Geoditic Vertical Datum), middle (-2.4 to 0.0 NGVD, eelgrass zone), and salt marsh. These valuable zones are all impacted by sediment.

Seasonal runoff of fresh water produces measurable turbidity in midestuary zones (eelgrass), the time duration of which is significantly longer than is the case in a simple flow system like a mature river (Phillips, 1984). Extensive land cultivation leading to siltation and the associated increase in turbidity leads to decreased eelgrass growth. Desiccation through increased sediment accumulation has been given as the major factor limiting the upper intertidal distribution of eelgrass. If eelgrass declines enough, increased erosion of bottom sediments could occur, diminishing the potential for eelgrass recovery. There appears to be no species succession in the eelgrass stage of the ecosystem. Eelgrass is the initial colonizer as well as the climax stage of development (Phillips, 1984).

The ability of eelgrass to exert a major influence on estuaries is due in large part to its rapid growth and high net productivity. Eelgrass stabilizes sediments in two ways. Leaves slow and retard current flow, reducing water velocity near the sediment/water interface which promotes the sedimentation of particles and inhibits the resuspension of organic and inorganic material. Secondly, rhizones and roots form an interlocking matrix which bonds sediment and retards erosion. The disappearance of eelgrass from an area leads to increased sediment grain size, water chemistry changes and increased circulation patterns and turbidity as well as significant changes in species composition which in turn leads to an expansion of the salt marsh.

The salt marsh, while increasing in area, does so at the expense of the eelgrass beds and deep water zones. Once established, salt marsh plant populations may persist or decline depending on environmental conditions that may differ greatly from those controlling establishment. With increased sedimentation, fresh water influence increases over tidal cycles and saltwater marsh vascular plants become dominated by lower-salinity tolerant species. Overall productivity will be greatly reduced in the estuary as this zone expands.

4. INVENTORY AND FORECASTING

4.1 Scoping of Concerns

The major concern of the sponsors is to reduce the sediment deposition in Morro Bay. Maintaining the Bay's biological resources, productivity, and aesthetic values is the concern of many agencies and local groups. Other environmental values such as those associated with recreation which are recognized as significant are protected by statute or administrative regulation.

A broad range of environmental, economic, and social concerns were assessed, and the significance of these factors in the selection of sediment reduction measures was evaluated (Table 2). Those having a significant effect on the selection of sediment reduction measures are rated high or medium. Concerns that will not be impacted by any proposed project alternatives or that have little significance in decision making are rated low or none. These are discussed briefly in Appendix B.

Table 2 EVALUATION OF IDENTIFIED CONCERNS

Economic Environmental and Social Factors	Degree of Significance to Selecting Sediment Reduction Measures
Wetlands	High
Erosion and Sediment Damage	High
Geologic Hazards	High
Human Health, Safety, and Quality of Life	High
Water Quality (Sediment, Turbidity)	High
Streams and Bay	High
Wildlife	High
Recreation	Medium
Visual Resource	Medium
Prime Agricultural Lands (lowlands)	Medium
Endangered/Threatened Plants and Animals	Medium
Fisheries	Medium
Groundwater	Medium
Land Use Changes	Medium
Transportation	Low
Irrigation	Low
Mineral Resources	Low
Air Quality	Low
Archaeological/Historical Resources	Low

4.2 Natural Resources

4.2.1 Soils

Current soils information show that many soils in the upper watershed are predominantly coarse-textured, shallow, and weakly developed. These soils generally occur on steep slopes over bedrock. They are grass covered and produce less than 400 pounds of forage per acre. Deeper medium or finer textured soils are typically located in valley bottoms or on gently rolling topography. These soils have high water-holding capacities and can produce 1,000 to 2,400 pounds of forage per acre annually. Some of these deeper soils in the watershed have been type-converted from brushland (chaparral) to grassland. Such a conversion would increase forage production and may increase water yield (Turner, 1986). Temporary increases in soil erosion would occur during the first four years as grass cover establishes.

4.2.2 Vegetation (Figure 2)

Brushland: The upland soils dominated by brush are also shallow soils. As coastal influences diminish, vegetation changes occur from coastal sagebrush and coyotebush to chamise (chaparral) dominated communities. The California Department of Forestry has indicated that most of the watershed has not burned during the last sixty years (Parker, 1989, California Department of Forestry). The absence of recent fires has produced an even-aged plant community over most of the northern area and is recognized by the US Forest Service as a potential wildfire problem area. The brushlands in the Clark Valley Area are now being managed with the cooperation of ranchers and California Department of Forestry under a vegetation management program to increase plant diversity through prescribed burns, which also reduces the potential for catastrophic sediment yield. If large wild fires occur in an even aged stand the potential of a large "pulse" of sediment could occur and over-tax the creek system's ability to move this sediment causing overbank deposition or relocation of some creek alignments.

Woodland: Dense stands of coast live oak (Quercus agrifolia) are located in the sandy and coarse textured soils influenced by the coastal climate. With higher rainfall on higher elevation sites in the watershed, some coarse-textured soils support conifer species. These include scattered populations of Coulter pine (Pinus coulteri) and Digger pine (Pinus sabiniana).

Riparian woodland is found along the banks of most creeks except where roads and agricultural activities have removed the mature vegetation. Willow (Salix sp.) and other woody vegetation

establishes if slope, land management and moisture conditions are adequate. Many riparian communities have been over-utilized in the watershed by livestock, resulting in reduced plant regeneration and low species diversity.

Sensitive plants are those with a high risk of becoming extinct. These species should be managed to maintain viable populations and prevent decreases which could lead to Federal listing as threatened or endangered species. The Cuesta Botanical Area is in the watershed and contains some of the 28 sensitive plant species identified in the Los Padres National Forest (USDA/Forest Service, 1988).

4.2.3 Wildlife

The watershed provides habitat for various species of wildlife. The oak woodlands provide cover and nesting sites for many species of song birds and raptors. The Morro Bay kangaroo rat (Dipodomys heermanni morroensis), a state and federally listed threatened and endangered species, is found in the southwestern portion of the study area. There are peregrine falcon nesting sites on Morro Rock. The falcon, a state and federally listed endangered species, hunts throughout the area. Sweet Springs, a fresh water spring in Los Osos, provides habitat for a diverse community in a small area. The Chorro Creek drainage has an anadromous fishery which has been adversely impacted by various activities which have reduced base flows and suitable spawning areas. The bay also provides habitat for fish and for birds which use this coastal estuary for breeding, food, and resting area during migration. The California clapper rail (Rallus longirostris obsoletus), a state and federally listed species and the California black rail (Rallus jamaicensis coturniculus), a state listed rare species, nest in the estuary areas of Morro Bay (Fish and Wildlife Service, 1981; M. Josselyn, 1989).

4.2.4 Streams and Wetlands

The natural drainages of Chorro and Los Osos Creeks provide water for infiltration into the shallow ground water basins for use by agriculture and urban interests. The ground water basins have safe annual yields of about 1500 acre feet for each basin (Tetra Tech, 1975). They also provide water for wildlife and the anadromous fishery in Chorro Creek. A few sites in the Los Osos Basin have elevated nitrate levels due to septic tank effluent (The Morro Bay Group, 1987). Fecal coliforms carried by stream water or currents into the bay have also impacted the shellfish industry on leased tidal land.

Morro Bay provides the largest area of salt marsh, lagoon, and estuary along the Central California Coast. It is one of the few relativity intact natural estuaries on the Pacific Coast of North America. Its interaction with the surrounding lands has resulted in increases of salt marsh and eel grass and a reduction in deep water habitat areas of the Bay (Josselyn et al., 1989). Other

areas of fresh water wetlands that exist throughout the study area include Warden Lake, Sweet Springs, and other wetlands both natural and man-made. These provide valuable sources of species diversity to the area.

4.2.5 Visual

Morro Bay and the surrounding region attract tourists throughout the year. The ocean, bay and surrounding area provide an outstanding diversity of recreational opportunities for thousands of people every year. The peaks which divide Chorro and Los Osos Valleys and those that surround the watershed provide visual contrasts to the ocean and hills.

4.3. Forecasted Conditions

The evaluation period of forecasted conditions for this plan is 25 years. Estimates were made of the volume of sediment yield from major sources of erosion. This will serve as baseline data to estimate the effects of the selected plan over the 25 year life of the project.

The Coastal San Luis Resource Conservation District contracted with Philip Williams and Associates to analyze the changes which have occurred in the Bay over the last 100 years (Haltiner, 1988). Differences in a series of bathmetric surveys completed on the Bay were analyzed. The results show a 25 percent average decrease in tidal volume over the last century with some areas showing greater decreases. Based on analyses of potential sources and sediment particle size, sediment yield is primarily attributed to sediment delivery from creeks (Morro Bay Erosion and Sediment Study, USDA/SCS 1989). These sediments are deposited throughout the central and south Bay areas, as well as in the delta and lower creek channels. On an average annual basis, the current rate of deposition entering the Bay from the watershed is approximately 37,000 cubic yards per year (Haltiner, 1988). The 37,000 cubic yards of sediment entering the Bay can be related to the estimated 45,500 tons of sediment estimated in the erosion and sediment study (Erosion and Sediment Study, Morro Bay Watershed, USDA, SCS 1989) by using a density of 94 pounds per cubic foot for sediment in Morro Bay. This would convert the 45,500 tons to 35,900 cubic yards. This is assuming that most of the sediment reaching Morro Bay is trapped in the estuary. The difference between these two estimates is 3 percent. However, Morro Bay is not a perfect sediment trap and Bay sediment is not this dense. The decrease in density will be balanced by the lower Bay trap efficiency.

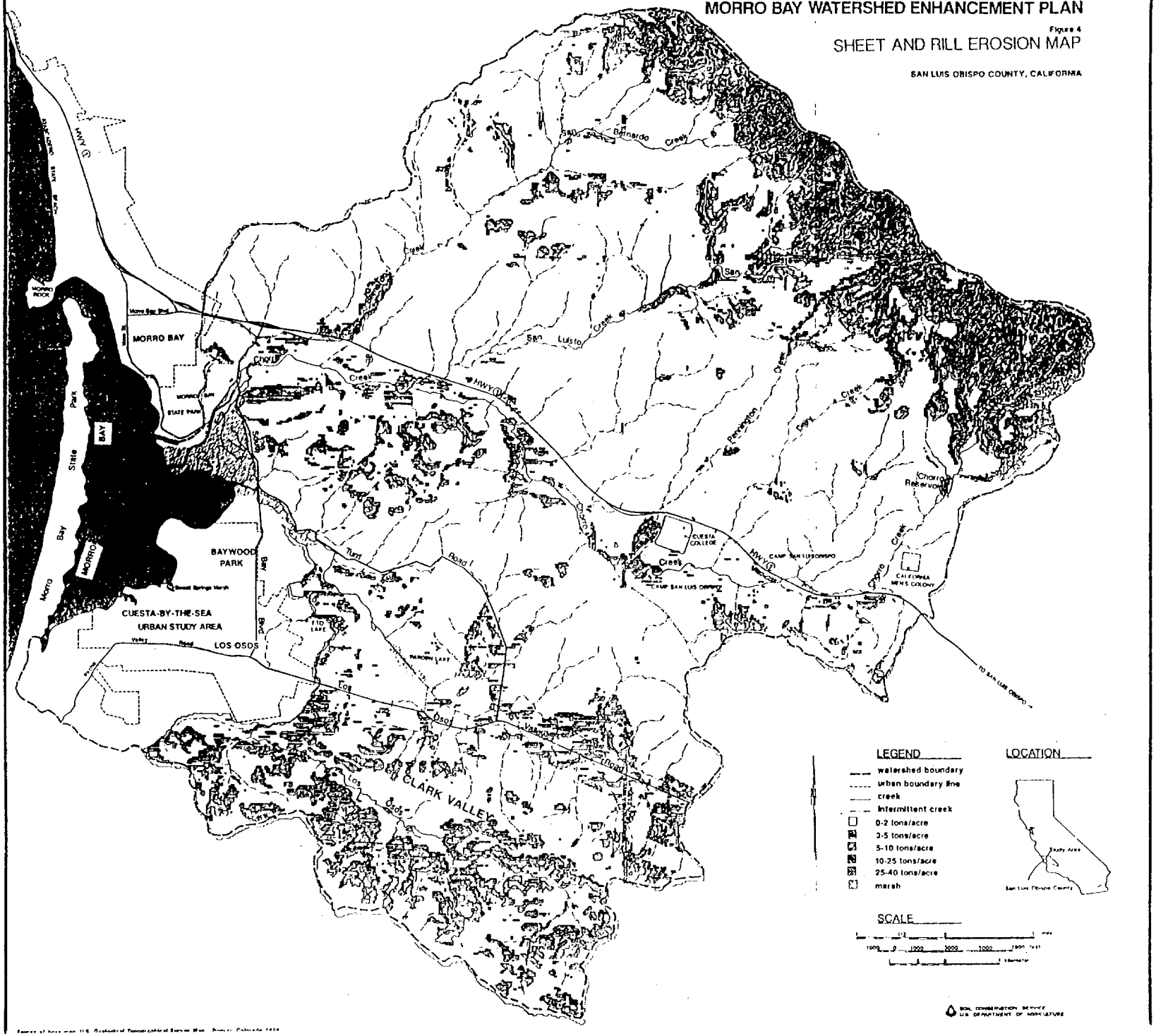
Current land use patterns (Table 1), based on the 1978 California Department of Water Resources Cropland Maps, were used to develop an estimate of sheet and rill erosion by crop or land use (Figure 4). The areas of each land use are not expected to change

MORRO BAY WATERSHED ENHANCEMENT PLAN

Figure 4

SHEET AND RILL EROSION MAP

SAN LUIS OBISPO COUNTY, CALIFORNIA



SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE

significantly during the next 25 years. It is not anticipated that the present agricultural ownership will be further subdivided. If, however, smaller land units were created and the number of access roads were increased, then the amount of sediment expected from roads would also increase.

Sheet and rill erosion in the watershed was computed using a computer model of the Universal Soil Loss Equation (USLE) (Table 3). Cover, rainfall, soils, and slope factors were used to estimate the erosion from cropland (three types), brushland, woodland, rangeland, and urban lands. Vegetative cover and land use management are the factors which are manipulated in the USLE model. A small increase in vegetative cover can result in a significant reduction in sediment. The erosion from roads, streams, and gullies was measured using a Direct Volume Method. The Direct Volume Method estimates the average annual thickness of bank or surface removed by erosion; this is multiplied by the area of bank or surface to give a volume estimate. The density of bank or surface soil was estimated to be 94 pounds per cubic foot. Sediment yield values from erosion sources are presented in Table 3. Figure 4 presents the erosion rates for the study area. After computation of gross erosion the sediment (from sheet and rill erosion) was mathematically routed through the watershed, using sediment delivery ratios from various points of origin to determine the sources of sheet and rill sediment delivered to Morro Bay (Table 4).

Table 3. SEDIMENT SOURCES TO MORRO BAY

Source of Sediment	Chorro Creek (Tons)	Los Osos Creek (Tons)	Watershed Total Annual (Tons)
Sheet and Rill	19,200	9,700	28,900
Percent of Total	42.3	21.3	63.6
Streambanks	6,000	3,400	9,400
Percent of Total	13.3	7.4	20.7
Roads	4,100	2,600	6,700
Percent of Total	9.0	5.7	14.7
Gullies	300	200	500
Percent of Total	0.7	0.4	1.1
TOTAL	29,600	15,900	45,500

Table 4. SHEET AND RILL SEDIMENT YIELD

Source of Sediment	Chorro Creek (Tons)	Los Osos Creek (Tons)	Watershed Total (Tons)	Total Sediment (%)
Brushland	9,400	4,300	13,700	47
Rangeland	5,200	2,500	7,700	26
Cropland	2,800	2,100	4,900	17
Woodland	900	400	1,300	5
Urban		400	1,300	5
TOTAL	19,200[1/]	9,700	28,900	100

1/ Includes 900 tons of sediment from the bay communities which enters directly into Morro Bay.

5. FORMULATION OF ALTERNATIVES

5.1 Introduction

Over 63 percent of the sediment reaching Morro Bay comes from sheet and rill erosion in the watershed (Table 3). Sediment yield to Morro Bay can be decreased by reducing the erosion rates from various upstream land uses. Most erosion control measures will also benefit the long term productivity of the land and will reduce maintenance of any sediment basins which may be installed.

Alternatives were developed to reduce sediment yield by increasing vegetative cover using management changes or measures such as drip irrigation and fencing. The installation of sediment basins was also examined to help reduce the total volume of sediment to the Bay. Alternative solutions were then formulated in terms of economic feasibility and local acceptability. Economic feasibility was based on cost comparisons of the measure to the cost of a locally acceptable dredging program in the Morro Bay Estuary, estimated at $10.00 per cubic yard.

In order to dredge the environmentally sensitive southern and central portions of Morro Bay, several features would be required. A winter dredging period (December through March) would be necessary since sea water turbidity is high at that time and visual impacts would be reduced. A pipeline would be required to release dredged sediment where the Army Corps of Engineers is presently disposing of its dredge materials from the harbor mouth. Land disposal of dredged sediments was not considered as an economically viable option. These two requirements will significantly increase the estimated costs. Factors include the shortened construction season, the possibility of winter storm damage, and increased capital costs to the contractor. The third requirement is one of developing a phased, mixed depth and alternate side dredging pattern to protect sensitive areas. This would help restore the areas of Morro Bay which have been impacted by sediment from the watershed. These areas include the intertidal mud flats which have filled an average depth of two feet and the salt marsh which has increased in area by 200 acres since the 1890's (USGS, 1897; Haltiner, 1988). By increasing the complexity of the dredging pattern, habitat diversity is increased thus allowing the undisturbed areas to serve as a gene pool of adapted species to help stabilize disturbed sites. The cost of a dredging project in the central and southern portions of Morro Bay is estimated to be ten dollars per cubic yard for a 400,000 cubic yard project. This is about twice the cost of dredging the mouth of Morro Bay harbor.

5.2 Treatment Measures

Alternative treatment measures were examined for their potential to reduce sediment yield. The costs of these practices were computed and their cost effectiveness were evaluated on the basis of reduced sediment yield. The following discussion explains the measures that were evaluated as a part of this study.

5.2.1 Measures for Roads

The treatments considered included rock lining inside ditches, planting disturbed areas, fencing disturbed areas, installing waterbars, regrading slopes, and constructing retaining walls for unstable areas. If new roads are built for subdivisions, the rate of road erosion will increase unless there are accompanying measures for erosion control. These measures were evaluated and rated for slight, moderate, and severe soil erosion conditions.

Five measures were evaluated for new road construction in the Morro Bay Watershed:

a. Grading: stabilize slope by shaping.
b. Critical area treatment: shape, seed, fertilize, and mulch.
c. Waterbars: inside ditch relief.
d. Retaining walls.
e. Fencing to protect vegetation where grazing is practiced.

Appropriate technical assistance would include education and training to maintain roads to reduce erosion.

5.2.2 Measures for Brushland

The relatively high erosion rate for mature brushland in the project area under future without project conditions is not expected to change in the long-term. Prescription burning, which could be a measure under a Coordinated Resource Management Plan, differs from wildfires in that five major elements can be controlled. These include fire intensity, season of the burn, burn frequency, areal extent and pattern of burning, and land use associated with the burn. All of the factors affect soil erosion to some degree. Generally, erosion increases with frequency of prescribed burns. Sheet, rill, and dry ravel erosion increase because the soil is exposed at more frequent intervals. Gains in erosion control realized with low-intensity, prescribed burns could be offset by burning more frequently. In areas where wildfires are expected every 30 years, assuming burns of equal intensity, it is known that prescribed burning on a 15-year cycle doubles the fire-related increase in erosion rate. However, allowing a 50 percent erosion reduction for low-intensity burns, a prescribed burning program would result in essentially the same amount of expected erosion as would occur under wildfire conditions.

Prescribed burning allows control over the area and pattern of burning, which can be used to produce erosion-controlling stands of vegetation. When combined with other measures such as firebreaks, road access, seeding, fertilization, and fencing, management and timing of soil erosion could be greatly enhanced. This would prevent a large "sluge" of sediment from an uncontrolled fire from exceeding the ability of the streams to carry coarse sediments. These coarse sediment could divert the creeks into new channels causing finer material to be moved as the creek established its new channel. This makes it possible to plan land use measures that will lead toward improved stability in the entire ecosystem.

5.2.3 Measures for Gully Control

Gullies form as a result of concentrated overland water flows. Gullies can be either actively eroding with sediment yield during every storm, healed with no bare soil areas and no upslope advancement, or partially stable with sediment produced only during extreme storm events. Erosion control would vary depending on the cause, slope angle, and size of area covered. Eliminating the concentrated flow, shaping the disturbed area, seeding, fertilizing, and mulching coupled with netting and fencing, if necessary, will control most gullies. The elimination of concentrated flow may require culverts or regrading for redirection of water flow. These practices can increase the cost significantly. Planting a tree filter at the outlet of a gully will provide a stable area for vegetation to grow and stabilize the bottom area of the gully. This results in trapping sediment, eventually reducing gully gradient. This barrier could also provide fuelwood production and cover for wildlife.

Two measures coupled with management through technical assistance were evaluated for gully treatment in the Morro Bay watershed:

a. Shape, seed, mulch, and fertilize.
b. Plant an outlet filter of trees.

5.2.4 Measures for Riparian Management

Streambank erosion can be reduced in some areas by clearing and snagging vegetation and debris from the center of the channel in some sections to provide enough clearance to divert flows away from the toe of the bank. This measure would allow the toe of the banks to reach a stable angle and reduce stream velocities along the banks to permit vegetation to establish and protect the bank. The growth of cattails and other emergent vegetation in channels which flow through cropland may be controlled by encouraging tree growth to shade the channel in order to help control this emergent growth. Measures for critical area treatment and selected planting can be implemented. In many areas vegetation would reestablish if grazing management was changed. In the summer, riparian areas serve as cool loafing

areas for livestock. Trampling of channel vegetation and banks results. Therefore, when stream flow begins there is a lack of vegetation to resist flow. This results in higher stream velocities and increased erosion. The practices evaluated for stream bank erosion include:

a. Clearing and snagging of vegetation.
b. Critical area treatment.
c. Shaping and tree planting.
d. Fencing and grazing management.
e. Grade control and streambank protection structures.

These measures were evaluated using streambank areas with erosion rates of slight, moderate and severe. There were four orders of streams for which "typical assessments" of each rating were developed and evaluated (Appendix D).

5.2.5 Measures for Rangeland

Sheet and rill erosion on rangeland can be reduced by increasing the standing grass cover during the critical period of the fall rains. This cover serves at least two purposes. It prevents the detachment of soil particles by raindrop impact and slows the velocity of the water as it flows over the soil surface. In addition to the reduction of direct impact erosion, organic residue allows increased infiltration with lower storm peaks and increased base flows. In order to accomplish an increase in cover, livestock control is necessary. This measure is basically a management practice, but certain tools may be necessary. These include fencing, water development, range seeding, deferred grazing, fertilization, integrated forage system development and stock trails or walkways.

The management methods selected would vary depending on the ranch operation. The range goals selected for this plan require a high level of technical assistance to develop and promote the conservation plans necessary for implementation of those practices designed for individual ranch operations. These plans would vary because each ranch has different needs and problem areas.

Changes in management will help provide protection to the riparian corridor while allowing periodic short term grazing. The benefits include re-establishment of bank vegetation and an increased trapping of sediment along the banks and in the corridor.

The tools which may be necessary to implement management changes for the riparian corridor include: fencing, channel revegetation, critical area treatment, filter strips, and structures for water control and delivery. These structures will provide watering areas for cattle, control small critical drainages and provide an inlet for stock water delivery.

In order to evaluate range practices, two "typical" areas were selected and management practices necessary for accomplishing the selected conservation plan goals were evaluated. The practices were considered effective in reducing erosion in range and riparian zones. The practices include:

a. Fencing to control livestock.
b. Planting summer forage.
c. Deferred grazing of selected areas and a planned grazing system.
d. Livestock water system development.
e. Channel vegetation management.

There is an increase in cost-effectiveness when a total ranch plan is developed. Total resources management makes it possible to develop interrelated measures which can serve multiple functions.

5.2.6 Measures for Small Pastures

This practice is intended for those small pasture and paddock areas in the study area where rangeland grazing is supplemented with purchased feed. The owner does not own enough land for a ranch and the animals may be 4-H projects, pets, or for personal consumption. Technical assistance and the installation of a fenced paddock area will reduce the net erosion from the remainder of the area. If a change is made to increase the number of parcels in the watershed then these small pastures could increase their sediment contribution. An increased level of technical assistance to provide the education to reduce erosion would be needed if these changes occur.

This practice was not evaluated for effectiveness because of the small area of the watershed currently involved.

5.2.7 Measures for Conservation Cropping

When a grain crop is in a rotation with garbanzo beans, the crop is usually harvested as hay. The stubble may be grazed. The practices applicable are conservation tillage, filterstrips, crop residue use, and cross-slope farming.

When planted to snow peas, row direction and irrigation are downhill. This can cause gully erosion coupled with sheet and rill erosion. Drip irrigation will solve the erosion caused by irrigation but cultural practices would have to be changed to cross-slope cultivation in order to more effectively reduce sheet and rill erosion. Sediment control practices and filterstrips can be used.

For this plan the following measures were evaluated:

a. Conservation tillage.
b. Drip irrigation on land planted to snow peas.
c. Cross-slope farming.

These measures were applied on categories of slight, moderate, and severe eroding fields.

5.2.8 Measures for Urban Areas

The primary reasons for sediment erosion from urban areas are: 1) poor culvert location and design which forces concentrated flows of water onto unprotected areas, and 2) exposure of bare soil surfaces during construction. The County of San Luis Obispo has constructed basins and has had to maintain areas where the culverts have eroded material from upland areas into streets and yards. The sandy fraction in Los Osos soils do not transport at a high rate to the Bay. To control construction erosion the following practices were developed and evaluated:

a. Seed, fertilize and straw mulch during construction to control soil erosion.
b. Erosion netting with landscaping.

The second practice was rated for reduction of sedimentation over two succeeding two year periods.

5.2.9 Treatment Development and Selection

Various treatment "levels" (combinations of measures) were developed for each erosion category. The levels were evaluated by comparing the additional cost of adding another measure to the level versus the additional cost per ton of sediment reduced. Measures were then imposed on the various stream orders[1/] found in the watershed.

As an example there were eight levels of treatments developed for second order streams. The cost of treatment varied between $4.92 and $46.13 per ton of sediment reduced. Three of the eight levels of treatment were selected. Each level of treatment controls a greater fraction of sediment. When the next level's cost resulted in a significant sediment reduction it was included; if not, treatment was held to the previous level. For slightly and moderately eroding second order streams, fencing was selected for cattle control and sediment reduction (@ $46.13 for

1/ Second order streams are the uppermost streams delineated on the standard U.S. Geological Survey 1:24,000 scale topographic quadrangle maps. A higher order stream reach begins at the junction of two lower order streams (Appendix D).

slightly and $10.93 for moderately eroding areas). For severely eroding second order streams, the selected treatment level included fencing for cattle control, clearing and snagging the centerline of the creek, and revegetation of bare areas with woody cuttings, estimated at $6.47 per ton of sediment. For severe second order streams, an increased cost of $1.57 more than the next level buys twice the sediment reduction. If the next level of protection for severe second order streams was selected, it would cost 325 percent more to achieve a 19 percent increase in sediment reduction.

Land Treatment Measures evaluated: (Code numbers refer to the combination of measures used to treat erosion at a given source and are identified in the LOTUS 123 LNDTRT spreadsheet. See Appendix C)

a. Fencing along rangeland roads on slightly and moderately eroding road cuts and fill slopes (1041, 1042, 1141, 1142): These measures are included as part of a range management plan because the roads in rangeland increase the amount of fencing necessary to control sediment from these sources. The increase in fencing is estimated to be one half mile of fence per mile of eroding road in rangeland. This measure reduces sediment from these sources 25 to 30 percent annually, depending on the condition of the cut or fill slope. The implementation of the range plan is necessary because management changes associated with the plan enable a reduced amount of fencing to control sediment from these sources.

b. Planting an outlet filter on medium and large gullies (4012, 4013): This planting can be used as a woodlot or wildlife area, depending on species selection. Costs for fencing, planting and selected plant materials are included. This measure will reduce sediment from the source by 50 percent due to outlet stabilization and increased vegetative growth into the bottom of the gully upslope. The planted area will also trap sediment by reducing the velocity of the water which causes sediment transported by overland flow to drop out.

c. Range management (5001): This measure involves changes in current management and the installation of the necessary practices to carry out these changes. This will vary in every operation and will require detailed analyses of the present operations. Practices which might be necessary include fencing, complementary forage systems, stockwater and planned grazing systems, and deferred grazing. Training can be provided at workshops and during the development of each ranch plan. The installation of measures will not reduce the sediment reaching Morro Bay, unless there is a corresponding change in management. This combination of measures coupled with appropriate management changes could reduce sediment delivered from rangeland by 60 percent.

d. Measures for snow peas (5011, 5013): These measures are for areas where snow peas are grown on slopes. In these areas it is estimated that up to 30 percent of a field would be eroding at less than two tons per acre. Measure 5011 would apply to those areas of sloping fields. Pea fields tend to be regular in shape; property boundaries or physical features dictate field shape. Because it is necessary to change cultural practices on a field basis, it is necessary to also treat the slightly eroding areas of a sloping field. Present cultural practices would need to be changed to include cross slope farming and drip irrigation, to reduce sediment from sloping pea fields by 40 percent. Cropping patterns will change depending on prices paid for agricultural products. If conversions are made to other crops, practices will still apply and will be effective in sediment reduction.

e. Conservation tillage in grain (5111, 5113): Measure 5111 applies to the flatter areas of a field, which is assumed to be 30 percent of the treated area. These practices include cross slope farming and provide for a residue of straw to remain on the soil surface covering 30 percent of the field after planting. This would reduce sediment from this source by 30 percent.

f. Measures for second order streams (2021, 2022, 2123): These measures apply to second order stream in rangeland where they are installed as part of a range management program. For slightly (2021), and moderately (2022) eroding streambanks these practices provide for additional fencing to control livestock in riparian zones. For severely eroding streambanks (2123), there are additional provisions for clearing and snagging the centerline of the creeks and for planting vegetation in bare areas of the streambank. When a ranch plan is developed, an inventory of the ranch is completed to establish the number of stream miles eligible for these measures.

g. Measures for third order streams (2031, 2032, 2133): The practice applications are the same as second order streams except that they are applied to third order streams in rangeland with ratings of slight, moderate, and severe erosion.

h. Measures for fourth order streams (3042, 3043): These measures apply to moderately (3042), and severely (3043), eroding fourth order streams. The measures include clearing and snagging the centerline of creeks and planting vegetation in bare areas along the streambank. When a plan is developed for the farm or ranch operation the number of streambank miles eligible for these measures will be determined.

i. Measures for fifth order streams (3052, 3053): These measures apply to moderately (3052) and severely (3053) eroding fifth order streams. The practices include clearing and snagging the centerline of creeks and planting vegetation in bare areas along the streambank. When a plan is developed for the farm or ranch operation the number of streambank miles eligible for these practices will be determined.

j. Measures for urban construction (6010, 6011, 6012): These practices are to reduce the sediment delivered when areas are cleared for homesites and when construction occurs during the wet season (6010) before installed landscaping can protect the soil from erosion (6011, 6012). The evaluation of urban post-construction erosion included year one (6011), and years two, three, and four (6012) after the home is constructed. The costs for installation were spread out over these two periods. The eligible measures include spreading straw out over the soil and fixing it in place by tucking or netting (6010). The post-construction landscaping practice is the addition of an erosion control blanket between plantings to cover the soil and prevent raindrop impact. A rain gutter system to control concentrated flow is also included.

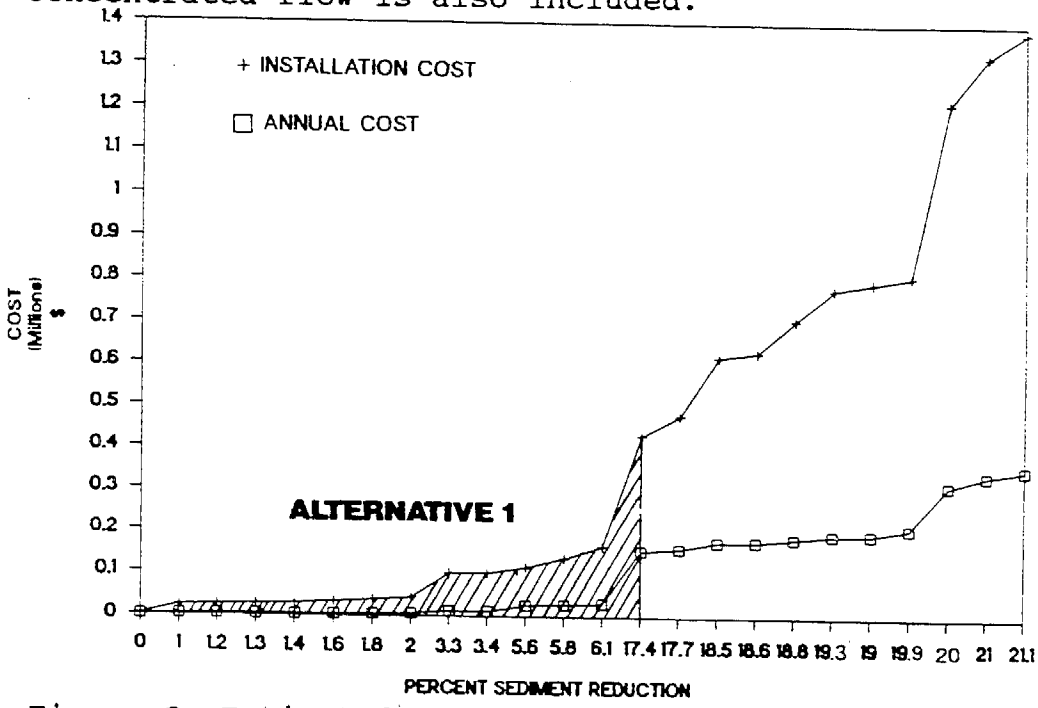


Figure 5. Estimated Cost Curve for Selected Treatments

Figure 5 represents the sediment reduction resulting from the installation of the 23 selected treatment measures. The measures were arranged in acceding order of dollars per ton of sediment reduction. The cost of installing each succeeding practice throughout the watershed was added to the previous cumulative cost. The cumulative percentage of sediment reduced by the installation of each selected treatment was also computed. These values were plotted to create the curve in Figure 5. The shaded area represents the treatments selected for Alternative 1. This cut off point was selected because the installation cost doubles for each 10 percent increase in erosion control beyond 17.4 percent.

5.2.10 Sediment Control Structure

This practice will trap and store sediment and prevent it from entering the Bay. When sediment is stored, it will eventually need to be removed if the basin is to continue to function. Once a sediment basin is installed there are operation and maintenance (O & M) costs associated with the structure. These costs can be reduced by minimizing sediment yield from the watershed. Sediment structures also remove the coarse materials necessary for fish habitat and the armoring of stream bottoms downstream of the structure. This may result in an increase of stream erosion if provisions are not made for protection of downstream areas.

Six structure locations were examined for the plan (Table 5, Figure 6). The trap efficiency, cost, and life expectancy of each structure was estimated. An evaluation period was used to determine if a clean-out of the structure was needed for computation of the annual cost. These annual costs were divided by the average volume of sediment trapped to obtain a cost per ton of sediment removed.

Two of the six sites (Table 5) would store sediment for less than ten dollars per cubic yard. The first is located on Chorro Creek directly upstream of South Bay Boulevard. This site is currently farmed but is a historic flow area for Chorro Creek. The creek is presently contained by a levee which defines the north bank of Chorro Creek and which would be removed. This sediment basin site could have multiple uses incorporated into its design. It could provide sediment storage, ground water recharge, shallow freshwater wetland, and recreational opportunities.

The second site is presently a natural wetland called Warden Lake. According to the SCS mathematical sediment routing, Warden Lake now traps approximately 30 percent of the sediment which reaches it. By modifying the outlet it is possible to increase the detention time to permit a greater percentage of the clay and silt to be trapped there instead of in Morro Bay. Provisions to prevent water table level increases in the surrounding cropland and a cooperative agreement among the landowners to create a 200 acre-foot reservoir on their properties would be needed before implementation can occur.

These two sites have advantages over the other four sites which include:

a. More storage capacity.
b. Larger drainage areas.
c. Lower cost per cubic yard of sediment stored.
d. No removal of gravels from spawning areas.
e. Longer detention time.

Table 5. SEDIMENT BASIN SITE COMPARISON

Site Location	Estimated Storage Volume (Acre Feet)	Percent Reduction of Annual Sediment (Volume)*
Warden Lake	200	10
San Bernardo Creek	35	5
San Luisito Creek	54	5
Pennington Creek	26	3
Dairy Creek	13	1
Chorro Creek	190	34
Los Osos Creek (considered, but not feasible for a basin, unless road flooding is permitted by the County)		

* These reductions do not include land treatment in the upper watershed areas.

5.3 Alternative Plans

No Project Alternative

Should no action be taken to reduce sediment yield from the watershed into the Morro Bay, an estimated 37,000 cubic yards per year will accrete in the Bay. This represents a loss of 540 acre feet of the tidal prism over a 25-year period, as well as other associated effects on the ecology of the Bay and its recreational potential. Prediction of impacts is difficult due to scarcity of definitive historical data on the biota. Most biological information has been collected during the last 30 years making historical trends and projections difficult (Josselyn et al, 1989).

The No Project Alternative effectively becomes a means of measuring the impacts of other alternatives, particularly the volume of sediment delivered to the Bay.

Alternative 1 developed for this plan concentrates on controlling sediment at the source (Table 6). The Morro Bay Watershed Erosion and Sediment Study (USDA/SCS, 1989) describes 23 land treatment measures evaluated to treat erosion at various sources identified in the watershed. Fourteen of these 23 were selected for further evaluation on the basis of cost per ton of sediment reduced by each measure (Table 6). Measures selected for detailed evaluation are discussed above (Land Treatment Measures a-j). For cost comparison of all three alternatives see Table 7. A detailed description of treatment measures studied is found in Appendix C.

Table 6. TYPICAL REDUCTIONS OF SEDIMENT BY MEASURE

Treated Area	Measures *	Sediment Reduction (Percent)
Roads	Waterbars & Revegetation	40
Brushland	Prescribed Burn	10
Critical Erosion Areas	Shape, Seed, Fertilize, Mulch	60
Rangeland	Fencing, Seed, Deferred Grazing	50
Riparian Areas	Fencing, Deferred Grazing	66
Riparian Areas	Clearing, Tree Planting	60
Pasture & Hayland	Paddock & Management	40
Dryland Grainland	Conserv. Crop. System	30
Pea Cropland	Conserv. Crop. System	20
Pea Cropland	Drip Irr., Cross-Slope Cultivating	50
Basin Areas	Store Sediment	90

* Refer to Appendix C.

Table 7. COMPARISON OF ALTERNATIVES

Alternative Number 1/	Cost of Alternative Installation	Description of Measures	Percent Sediment Reduction
1	$444,000	Install 14 treatment measures in watershed.	17
	$163,000	Technical assistance.	
	$607,000	Total Alternative 1	
2	$1,510,000 2/	Install sediment basin on Chorro Creek.	34
	$20,000	Geotechnical investigation.	
	$30,000	Design sediment basin.	
	$30,000	Environmental evaluation.	
	$45,000	Contract administration.	
	$1,635,000	Subtotal 3/	
	$210,000	Install sediment basin on Warden Lake site.	10
	$10,000	Geotechnical investigation.	
	$20,000	Design sediment basin.	
	$25,000	Environmental evaluation.	
	$25,000	Contract administration.	
	$290,000	Subtotal 4/	
	$1,925,000	Total Alternative 2.	44
3	$2,532,000	Combination 1 and 2.	47 5/

1/ Alternative number values are those of alternative numbers 1, 4, and 5 from the Erosion and Sediment Study, Morro Bay Watershed, USDA, SCS, 1989.

2/ This value includes an estimate of the cost of acquiring land to install the sediment basins. The value is for planning purposes only and is not intended to represent actual market value.

3/ Alternative number 2 Erosion and Sediment Study, Morro Bay Watershed, USDA, SCS, 1989.

4/ Alternative number 3 Erosion and Sediment Study, Morro Bay Watershed, USDA, SCS, 1989.

5/ Sediment control is not additive for these combinations. When land treatment is included, the sediment reaching the sediment basins is reduced so that they will catch less sediment per year. The cost for maintenance is reduced because the basin on Chorro Creek would not need to be cleaned out after 19 years of operation.

Alternative 2 includes the installation of two sediment control structures (described in Section 5.2.10) to trap the sediment before it reaches Morro Bay. The site on Chorro Creek would need to be cleaned out before the end of the 25-year evaluation period. This increases the annual cost of trapped sediment by $40,000. If both sediment basins previously discussed are constructed, the net reduction of sediment would be 44 percent (See Morro Bay Erosion and Sediment Study) at an estimated total cost of $1,925,000.

Alternative 3 includes a combination of the first two alternatives. This alternative reduces the average amount of sediment by 47 percent and provides the greatest reduction of the clay fraction from all erosion sources (See Erosion and Sediment Study, Morro Bay Watershed) at an estimated total cost of $2,532,000. The inclusion of land treatment in this alternative also reduces the sediment contribution from Los Osos Creek which is not controlled by Warden Lake. The potential exists for a sediment basin near the outlet of Los Osos Creek. However, there is no feasible way of building a site on public land without flooding Turri Road. According to the County Roads Department, this is not acceptable to the County of San Luis Obispo because of the need for public access to the transfer station off of Turri Road. If Turri Road was relocated the area considered is part of the state park. An agreement and plan would need to be developed. This location was dropped from further consideration for this plan.

Alternative 3 also considers the urban treatments as part of the stipulated erosion control measures which are necessary to meet the requirements for a building permit. Many of the practices have other benefits in addition to erosion and sediment control. For example, drip irrigation in peas has produced increased yields (UC Cooperative Extension, personal communication); reduced tillage in a grain crop can reduce the net cost of producing a crop; increased cover in creeks increases wildlife diversity, and controlled burn programs can increase water yield. These benefits were not evaluated for this plan.

Evaluation of a practice involved comparisons of the cost of the practice's sediment reduction to the cost of removing an equal amount of sediment from Morro Bay by dredging. The selected land treatment measures are included in Table 8.

Installation of the measures listed in Table 8 extends the time required between dredging for each sediment control structure. The Chorro Creek site would need to be cleaned out 29 years after installation, an increase of ten years. If these land treatment measures are installed, the Warden Lake site would need to be cleaned out every 100 years rather than every 58 years without the project.

Technical assistance would include the development of ranch plans for landowners in the watershed. Workshops would be conducted relative to fencing, riparian management, conservation tillage, planned grazing systems and other training needed to inform the local landowners of the benefits of sediment reduction and

implementation of these measures on their properties. Technical assistance will also involve working with landowners to develop plans for the installation of these practices in areas other than rangeland. This includes working with local agencies to help in developing guidelines in erosion control, stream maintenance, wildlife development and to develop and maintain a good working relationship between landowners and public agencies.

Table 8. ESTIMATED INSTALLATION COSTS FOR SELECTED LAND TREATMENT MEASURES

Study Code Number	Measures*	Quantity Installed	Units	Estimated Installation Cost	Sediment Reduction (tons)	Cost Per Ton Sed.
2133	Fncng, C&S, Rvg	1	Mi.	$6,800	38	$4.13
1142	Fence, Rng pln	55	Mi.	$21,500	449	$5.06
1042	Fence, Rng pln	9	Mi.	$3,500	378	$5.06
3043	Reveg, C&S	0.1	Mi.	$1,000	28	$5.67
3053	Reveg, C&S	0.2	Mi.	$2,300	56	$6.09
2123	Fnc, Rvg, C&S	0.6	Mi.	$4,000	88	$6.47
2032	Fencing	1.7	Mi.	$6,600	86	$7.02
3042	Reveg, C&S	1.0	Mi.	$4,500	76	$10.57
2022	Fencing	18	Mi.	$57,000	604	$10.93
3052	Reveg, C&S	0.3	Mi.	$1,500	23	$11.25
5113	Grain, Con Tll	696	Ac.	$13,900	1009	$13.79
1141	Fnc, Rng Pln	56	Mi.	$21,800	104	$22.24
1041	Fnc, Rng Pln	75	Mi.	$29,300	140	$22.24
5001	Range Mngmt.1/	25,632	Ac.	$270,300	5152	$23.88
TOTAL				$444,000	8231 tons	

* Fncng, Fnc = Fencing
C&S = Clearing and Snagging
Rng pln = Range Planning.
Reveg, Rvg = Revegetation
Con Tll = Conservation Tillage

* Each measure addresses a different level of soil erosion as defined in Section 5.3.

1/ Include $5,000 for demonstration projects.

6. IMPLEMENTATION OF THE RECOMMENDED PLAN

The Recommended Plan (Alternative 3) incorporates the 14 proposed combinations of measures (Table 8), the two sediment basins, and technical assistance to reduce sediment yield to Morro Bay. The areas where these and other measures should be considered are shown in Figure 6. The remaining ten of the twenty-six measures evaluated could be installed but they are not included in the plan since they did not meet the planning criteria of cost-effectiveness. The total sediment reduction with implementation of the Recommended Plan is estimated to be 47 percent annually. This report would be incomplete if it did not point out the resources needed, and responsibilities which are necessary for someone to ensure the proper implementation of this plan. Since sources of funding for implementing the plan have not been firmly identified at this time, one of several possible methods of implementation was selected to demonstrate what would be needed.

6.1 Technical Assistance and Land Treatment

The Coastal San Luis Resource Conservation District (RCD) in cooperation with the SCS presently offers technical assistance to help solve resource problems in the Morro Bay Watershed. If this plan is approved, technical assistance would need to be increased for assistance to landowners, organization of workshops, coordination of permits, and development of treatment measures. An Engineering and Technical Service Agreement would need to be developed with the RCD to provide the technical assistance, and specifications necessary for implementation of the plan. Costs for these measures may also be eligible for Agricultural Stabilization and Conservation Service (ASCS) cost-sharing if they met applicable SCS specifications and are approved by the ASCS County Committee. Plans developed under the Enhancement Plan would be approved by the RCD and a committee of local landowners who would set priorities, approve estimated costs, and cost share for each approved plan. The cost share under the Enhancement Plan would be paid upon certification by the RCD's technical contractor of compliance to plan specifications.

6.2 Chorro Creek Sediment Basin

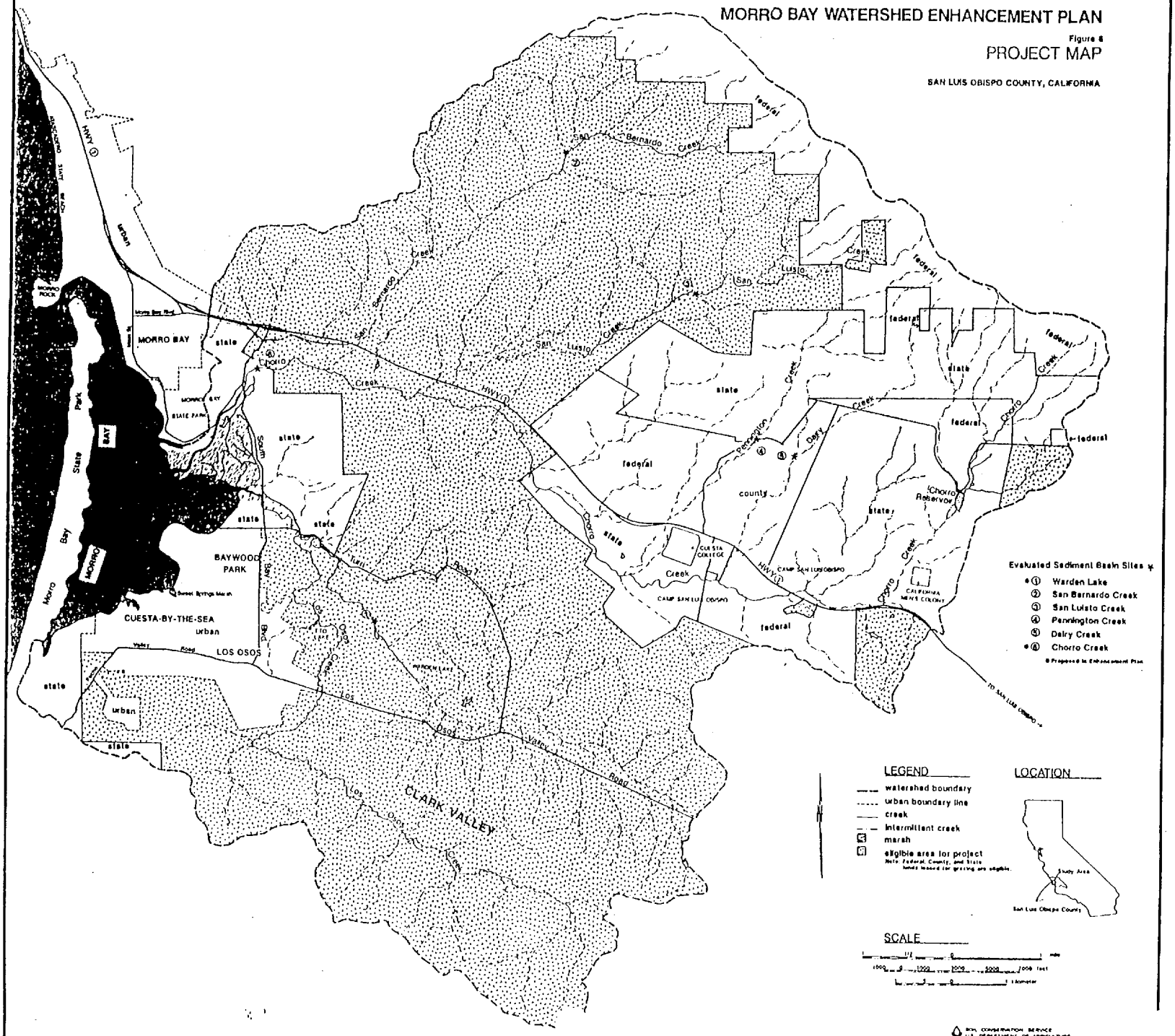
Purchase of the 60 to 120 acres needed for the proposed sediment basin would need to be negotiated by a public agency. A site upstream from the one located in Figure 6 may prove to be more cost effective and meet plan goals. Alternate sites will be developed and evaluated during the negotiation process. Funding to develop and construct the sediment basin with riparian restoration, fresh water habitat enhancement and other uses could potentially be provided by the California Coastal Conservancy.

MORRO BAY WATERSHED ENHANCEMENT PLAN

Figure 6

PROJECT MAP

SAN LUIS OBISPO COUNTY, CALIFORNIA



Source of base map: U.S. Geological Topographical Survey Map. Denver, Colorado 1978. Ownership boundaries based on San Luis Obispo County Plat Maps.
Note: This map for reference purposes only. Official maps, showing precise property lines and land use category boundaries, are on file in the County Planning Department.

SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Some other uses could include fisheries enhancement, recreation and continued agricultural production. An operation and maintenance agreement for the site would need to be implemented by the funding agency, the project sponsor and/or a local public agency.

6.3 Warden Lake

The present lake outlet is a 60-inch culvert which allows water from property north of the lake to pass under an access road. The water passes along the base of the old Los Osos landfill and joins Los Osos Creek west of the site. An agreement would need to be worked out between landowners sharing the site and the project sponsor to allow a permanent pool on private property and for maintenance of the installed structural works. The design of the new outlet would establish a 190 acre-foot pool which would cover the existing site to an average depth of 4 feet. The farm land east of the site currently has high water table problems. The outlet design needs to incorporate measures which will ensure that it does not contribute to an increase in water table level in that area. The RCD with the help of a project advisory committee could work to develop this agreement. The RCD, or other sponsoring agency would then develop a design which would both increase the sediment trap efficiency of Warden Lake and satisfy landowner concerns about increased water table levels.

6.4 Permits and Compliance

A streambank alteration agreement with the California Department of Fish and Game may be required for construction of some of the land treatment measures. These would include clearing and snagging, and revegetation work on critically eroding streambank areas. Construction and maintenance of the two sediment basins could require concurrence and/or permits from the following agencies (Figure 7):

Agency	Permit Name
Calif. Dept. of Fish & Game	Streambank Alteration Agreement
U.S. Army Corps of Engineers	Dredge and Fill (404 permit)
U.S. Fish and Wildlife Service	Concurrence (Dredge & Fill)
Calif. Dept of Water Resources	Water Rights (Storage)
Calif. Coastal Commission/Co. of San Luis Obispo	Coastal Permit
County of San Luis Obispo	Grading Permit

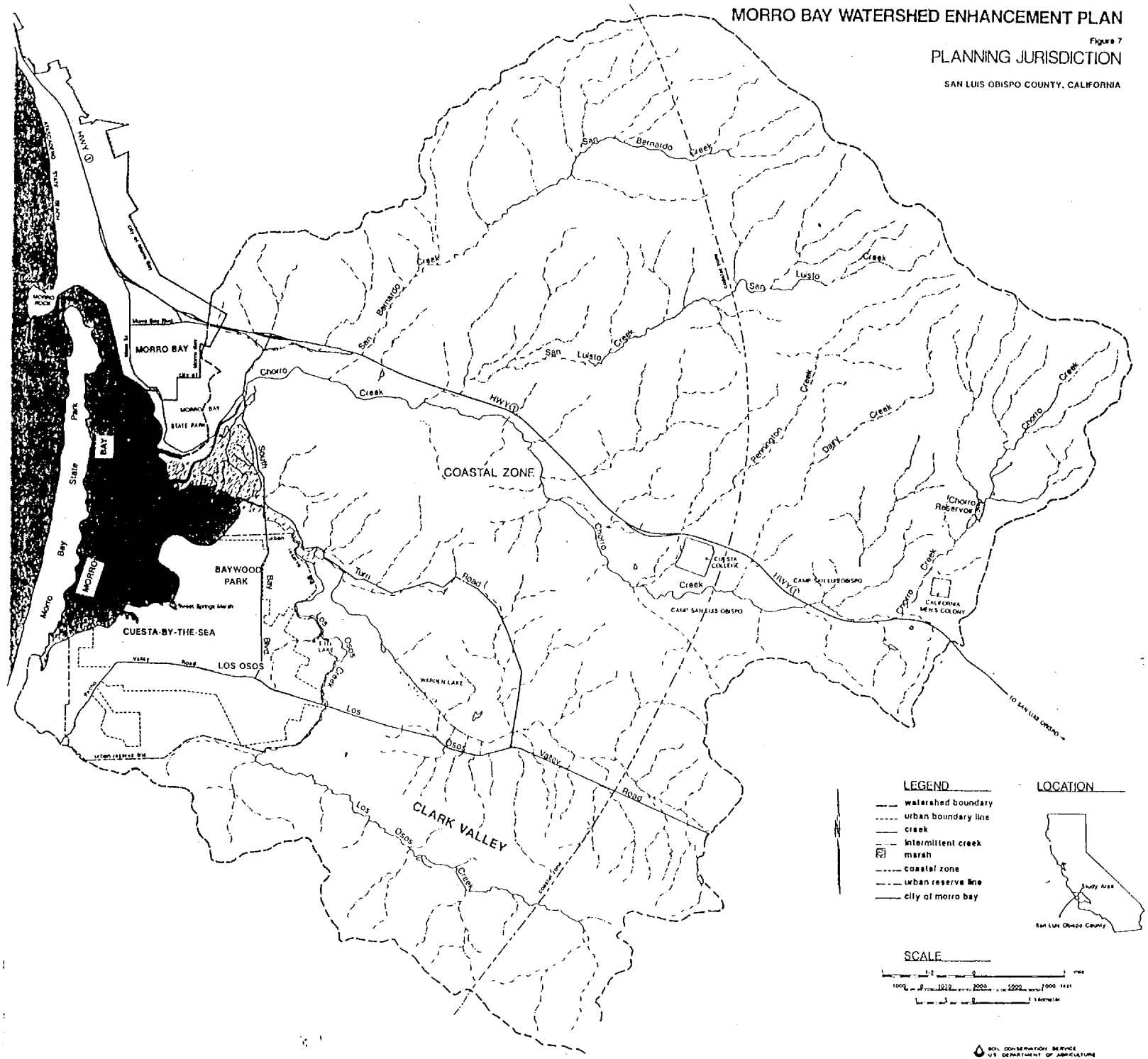
It would be more efficient to consolidate the permit process for both sites and let contracts for construction at the same time. These permits would need to be obtained prior to the construction of each basin.

MORRO BAY WATERSHED ENHANCEMENT PLAN

Figure 7

PLANNING JURISDICTION

SAN LUIS OBISPO COUNTY, CALIFORNIA



Source of base map: U.S. Geological Topographical Survey Map, Denver, Colorado 1978. Planning Zones based on Local Coastal Plan for San Luis Obispo County.
Note: This map for reference purposes only. Official maps showing precise property lines and land use category boundaries are on file in the County Planning Department.

SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Use of the Chorro Creek site for a sediment basin and riparian restoration would possibly require a land use amendment in local coastal plans.

6.5 Costs

Implementation of the Enhancement Plan would require funding for design and construction of the sediment basins, land acquisition where necessary, technical assistance, and installation of land treatment practices. Sources of cost-sharing presently exist and could be obtained for selected elements of the plan. The ASCS provides cost-sharing to farmers and ranchers for practices which reduce erosion and sediment in their operations. The California Department of Fish and Game can provide funding for the creation or improvement of fresh water wetlands. Private funding sources may also exist for wildlife and fishery enhancement. Funding for practices not mentioned in this plan could be added with the agreement of the funding agency, the RCD, and landowner. Public cost share funds under this plan would be those funds contributed by various public agencies to benefit Morro Bay. These funds would be used to both encourage the installation and partially offset the cost of treatment measures installed under the plan.

The public contribution for installation of the selected treatment measures (Table 9) was based on one ton of sediment reduction being equivalent to one cubic yard reduction of sediment reaching Morro Bay. This would be true if the density of sediment is approximately 74 pounds per cubic foot. The usual estimate for the type of sediment found in the bay is between 70 and 90 pounds per cubic foot. With a density of 90 pounds per cubic foot, a cubic yard would weigh 20 percent more than one ton (i.e. 2,400 pounds). However, land treatment measures reduce the mobilization of the particles which most impact the bay (clays and silts). A maximum ten dollar public cost share was selected to reflect the estimated cost of dredging and removing one ton of sediment from Morro Bay. Public contributions ($17,000) is defined as financial assistance provided under the Enhancement Plan for installation of the selected treatment measures. It is assumed that this money is from public agency funds to private land owners to partially offset the cost of the installation of these measures because of the public benefit of sediment reduction to Morro Bay.

The remaining costs for the treatment measures would be paid for by the landowner, with or without other sources of funding he or she may be eligible for under other programs when a Conservation Plan is developed. For each landowner the annual amount of sediment reduced to Morro Bay by installation of the plan would be estimated for each of the eligible practices. This reduction measured in tons, would be necessary to compute the amount of funding to be received under the Enhancement Plan.

Before the design of the two structures begins, a geotechnical investigation would need to be done on the sites for the proposed embankments and the borrow areas. This would ensure that the sites were adequate and feasible. The estimated cost for this investigation is $30,000.

If the technical assistance portion of this plan were implemented, it would cost approximately $40,000 per year for four years. This would include a major portion of the salary and benefits for an employee and staff assistance in the watershed area when workshops or other technical assistance are required. An additional $3,000 spread over four years would be needed for miscellaneous clerical assistance and graphics services.

Cost of modifying the Warden Lake outlet is estimated at $210,000 for construction and $45,000 for design and contract administration (Table 10). The storage and height of the structure can be held below California Department of Dam Safety limitations which would decrease the permit costs and design requirements. A more refined cost estimate can be completed after design. The design process would begin after the agreements with the landowners are executed.

The Chorro Creek site construction cost estimate is $600,000 (Table 10). After the site is purchased, the RCD or local sponsor would need to complete the design, obtain permits, and administer the construction contract. The estimated cost for design of the structure is $30,000. The cost for contract administration and inspection is $45,000. The cost for construction could be lower but detailed surveys and a more refined design needs to be completed before this can be estimated.

The impacts of the proposed basins need to be evaluated during the design process. An Environmental Assessment would need to address the changes which would occur in the bay and surrounding area. Water regime, fresh water/salt water balance, temperature changes, nutrient balance, fish passage, land use changes, and other impacts of each basin would need to be evaluated as part of the design process. The assessment for each basin would be prepared and circulated for agency and public review. The estimated cost of the Environmental Assessment for the basin on Chorro Creek is $30,000. This is due to the fishery and fresh water wetlands which could be impacted by this structure. The estimated cost of the Environmental Assessment for the structure on Warden Lake is $25,000. There appear to be fewer impacts which need to be evaluated for this site.

Table 9. ESTIMATED PUBLIC CONTRIBUTION VALUES FOR LAND TREATMENT

Study Code Number	Measures *	Quantity Required	Units	Estimated Public Funds	Sediment Reduction (tons)	Public Cost Share Rate**
2133	Fncng, C&S, Rvg	1	Mi.	$ 6,800	38	$4.13
1142	Fence, Rng pln	55	Mi.	21,500	449	5.06
1042	Fence, Rng pln	9	Mi.	3,500	378	5.06
3043	Reveg, C&S	0.1	Mi.	1,000	28	5.67
3053	Reveg, C&S	0.2	Mi.	2,350	56	6.09
2123	Fnc, Rvg, C&S	0.6	Mi.	4,000	88	6.47
2032	Fencing	1.7	Mi.	6,600	86	7.02
3042	Reveg, C&S	1.0	Mi.	800	76	10.00
2022	Fencing	18	Mi.	6,100	604	10.00
3052	Reveg, C&S	0.3	Mi.	300	23	10.00
5113	Grain, Con Tll	696	Ac.	10,100	1009	10.00
1141	Fnc, Rng Pln	56	Mi.	1,100	104	10.00
1041	Fnc, Rng Pln	75	Mi.	1,400	140	10.00
5001	Range Mngmt.	632	Ac.	$51,500	5152	$10.00
TOTAL				$117,000	8231 tons	

* Fnc, Fncng = Fencing
C&S = Clearing & Snagging
Rng Pln = Range Planning
Rvg, Reveg = Revegetation
Con Tll = Conservation Tillage

** Money per ton of sediment reduction to Morro Bay.

Table 10. SUMMARY OF PLAN COSTS

Technical assistance (4 years)	$163,000
Geotechnical Investigation	$ 30,000
Chorro Creek Sediment Basin	
Acquisition Costs[1/]	$910,000
Construction	$600,000
Design	$ 30,000
Contract Administration	$ 45,000
Environmental Assessment	$ 30,000
Warden Lake Sediment Basin	
Construction	$210,000
Design	$ 20,000
Contract Administration	$ 25,000
Environmental Assessment	$ 25,000
Land Treatment Practices	
Public Cost-Share	$117,000
Local Owner Share[2/]	$327,000
TOTAL COST	$2,532,000

1/ This figure is for planning purposes only and is not intended to represent market value.
2/ Eligible for Other Cost-Share Assistance.

6.6 Installation and Responsibilities

The installation period for the Enhancement Plan is four years. The proposed order of installation is described in Table 11.

The Coastal San Luis Resource Conservation District (RCD) could enter into cooperative agreements with landowners who wish to participate in the land treatment program. The landowner would acquire the necessary permits, licenses, and other entitlements for installation of the land treatment measures. The RCD would provide leadership for an aggressive educational program to encourage application of the land treatment measures.

Before land treatment measures are applied, the landowner and the RCD would enter into a Cooperator Agreement. The landowner would be invited to attend workshops sponsored by the RCD in order to develop an understanding of the management changes and practices necessary to decrease sediment and increase livestock carrying capacity. The landowner would also enter into a Long-Term Contract to install those recommended land treatment practices that are acceptable to the landowner.

Table 11. PROPOSED INSTALLATION SCHEDULE

Year	Activity	Expenditure
1	Prepare Chorro Creek Site Design & Warden Lake Modification.	Secure Permits for Construction.
	Prepare thirty-three Percent of Ranch Plans.	Technical Assistance and Workshops.
2	Prepare thirty-three Percent of Ranch Plans.	Technical Assistance.
		Install Warden Lake Modification and Chorro Creek Sediment Basin.
	Implement thirty-three Percent of Ranch Plans.	Technical Assistance and Workshops.
3	Prepare thirty-three Percent of Ranch Plans.	Technical Assistance.
	Implement thirty-three Percent of Ranch Plans.	Technical Assistance and Workshops.
4	Implement thirty-three Percent of Ranch Plans.	Follow-up Assistance and Workshops.

Each individual would work directly with the RCD or sponsoring agency, if these agencies are involved with the technical assistance, in developing a land treatment plan for their property. The landowner may install measures personally or may use the services of a contractor. Should a landowner have a contractor install land treatment measures, it would be the landowner's responsibility to administer the contract.

The land treatment contract may be from five to ten years in length. Practices and land units included in the contract would be identified during detailed on-site planning activities with the participant. Land units are estimates and may vary when practices are actually installed. All installed practices must meet SCS standards and specifications and must be installed at least three years before the contract ends.

Cost-sharing would be based on the cost-share values listed in Table 9. Participation at this cost-share rate would not be reduced if this plan is also eligible for cost-sharing from other sources. Landowners would submit invoices to the RCD certifying the quantities used. The RCD or sponsor would certify the technical adequacy of the measures installed.

If archeological or cultural resources are encountered during installation and construction, work would be halted. The sponsoring agency would notify the State Historic Preservation Officer and the National Park Service to determine the need for recovery.

If implemented as described above, the RCD or sponsoring agency would prepare conservation plans and Long Term Contracts, as well as design practice measures. The RCD or sponsoring agency would also assist the land owner in meeting permit requirements. After construction the sponsor would inspect the construction of land treatment measures and certify the proper installation of the land treatment measures.

Before construction could begin on the two sediment basins a local sponsor would have to assume the lead in obtaining the necessary permits and agreements, administer the contract, and assume responsibility for the operation and maintenance of the structures.

7. EFFECTS OF THE RECOMMENDED PLAN

7.1 Sediment Reduction

If the Recommended Plan is implemented, sediment delivered to Morro Bay will be reduced by 47 percent of the current annual rate (45,500 tons annually). Suspended sediment passing through the sediment basins will also be somewhat reduced due to increased plant cover and reduced clay mobilization. Some annual maintenance of the reservoirs will be required. This could be done under contract with a designated contractor.

7.2 Erosion Reduction

Control of bank erosion in the creek system would improve wildlife values and increase subsurface flows as creek bottoms are raised. The improved vegetative cover would also increase the sediment removal capacities of the creeks until a new equilibrium condition is reached. Reduced erosion from rangeland would increase range productivity as nutrient loss associated with erosion is reduced.

7.3 Social

The reduction of sediment to Morro Bay would have a positive impact on the biota of the estuary and the related positive effects on tourism, aesthetics, aquaculture and local recreation. This plan may also provide a focus for other projects which may serve to further reduce sedimentation of the bay or actually increase the tidal prism by dredging the bay. The increase in plant cover and species diversity may also improve the economic viability of ranching operations in the watershed.

7.4 Other Environmental Effects

During construction of any erosion control measures or structures in the creeks, there will be some disturbance of wildlife and some loss of riparian vegetation. The disturbance can be minimized by completing construction during periods other than the breeding season and mitigated with replanting to replace the vegetation lost to the structural installation. Visual impacts would be minimal. The sediment basin structure on Chorro Creek would be designed and landscaped to produce a minimal adverse visual impact and to increase riparian cover. Other structures are not visible from roadways. However, they would also be designed to minimize adverse visual impact. The remaining practices would improve the appearance of the stream corridor by increasing the vegetation in the area. A subsequent increase in vegetation would also lower water temperatures thus benefiting aquatic life. Table 12 presents the effects on resources of principal national recognition.

TABLE 12. EFFECTS OF THE RECOMMENDED PLAN ON RESOURCES OF PRINCIPAL NATIONAL RECOGNITION

Types of Resources	Principal Sources of National Recognition	Measurement of Effects
Air Quality	Clean Air Act, as amended (42 U.S.C. 185h-7 et seq.)	No long-term effect.
Areas of Particular Concern Within the Coastal Zone	Coastal Zone Management Act of 1972, as amended (16 U.S. C. 1451 et seq.)	Two structures proposed in zone, changes of use
Endangered and Threatened Species Critical Habitat	Endangered Species Act of 1973, as amended (16 U.S. C. 1531 et seq.)	No adverse effect
Fish and Wildlife Habitat	Fish and Wildlife Coordination Act (16 U.S.C. Sec 661 et seq.)	120 miles of fence with management changes will benefit wildlife cover
Floodplain	Executive Order 11988, Floodplain Management	Increase sediment storage
Historic and Cultural Properties	National Historic Preseration Act of 1966, as amended (16 U.S.C. 1531 et seq.)	Not present in study area
Prime and Unique Farmland	CEQ Memorandum of August 1, 1980: Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing the National Environmental Policy Act	60 to 120 acres would be converted to a sediment storage area.
Water Quality	Clean Water Act of 1977 (33 U.S.C. 1251 et seq.)	Reduced turbidity in Morro Bay will benefit eelgrass zone.
Wetlands	Executive Order 11990, Protection of Wetlands Clean Water Act of 1977 (33 U.S.C. 1251, et seq.)	Increased wetlands in sediment basins and along creek corridors.
Wild and Scenic Rivers	Wild and Scenic Rivers Act, as amended (16 U.S.C. 1271 et seq.)	Not present in study area

7.5 Irreversible and Irretrievable Commitment of Resources

The Chorro Creek site would be changed from strictly an agricultural use to an integrated sediment storage, wildlife, recreational, water infiltration area, and possibly some continued agricultural use. The associated income produced through agricultural use would be lost to the economic base of the area. Construction, operation, maintenance and management of the installed measures would require irretrievable commitments of energy, materials, and finances.

7.6 Short Term Versus Long Terms Use of Resources

The proposed project is compatible with projected future long term use of the area's land, water, and other natural resources. A possible short term impact of the project would be temporary traffic pattern disruption and inconvenience to nearby residents and tourists while the Chorro Creek sediment basin is constructed. Ranchers in the area may need to defer grazing some areas to encourage the establishment of vegetative cover in disturbed areas.

7.7 Relationship to Land and Water Plans, Policies, and Controls

This plan is consistent with the San Luis Obispo County Local Coastal Plan except that the Chorro Creek site may require a change in the Land Use Ordinance from agriculture to the new proposed use. Project installation would reduce the amount of sediment reaching Morro Bay. It would promote the aims of existing and potential users of the Bay as outlined in the Morro Bay Agency Task Force (see Public Participation Section) minutes and does not conflict with any of the group's programs for the Bay.

7.8 Conclusion

It is possible to reduce the rate of sedimentation in Morro Bay with the recommended plan. This plan was developed to minimize environmental impacts but some questions still need to be answered before the plan is fully implemented.

Implementation of the land treatment portion of the plan involve changes in agricultural practices and changes in land management which reduce impacts of agriculture on Morro Bay. Installation of these practices should not cause significant adverse environmental impacts.

The effects of the installation of the sediment basins on the bay and surrounding areas would need to be evaluated during the design process. Concerned agencies and the public would need to be contacted and their concerns addressed during the design process. The Environmental Assessment for the basins while concurrent to the design process requires a different forum and

procedure. The Morro Bay Agency Task Force and Friends of Morro Bay are two groups addressing research needs for the bay. These two groups would be instrumental in helping the environmental process to go smoothly.

The public agencies, (federal, state, and county), which own large amounts of land in the watershed could coordinate their management plans to reflect the best management practices for the uses that meet their goals and reduce sediment to the bay. The Morro Bay Agency Task Force could be used to develop memorandums of understanding and goals for the Coordinated Resource Management Plan for the agencies and their tenants.

8. CONSULTATION AND PUBLIC PARTICIPATION

8.1 Public Participation

A joint agreement under Public Law 74-46 between the Soil Conservation Service and the Coastal San Luis Resource Conservation District to provide an enhancement plan for Los Osos and Chorro Creeks in the Morro Bay Watershed was approved by both parties during August, 1987. During the same month, an initial meeting was held in Morro Bay with interested watershed residents and landowners. Thirty landowners and concerned individuals participated in the meeting during which details and objectives of the erosion control study were discussed.

In September 1987 a second project meeting was convened in Morro Bay during which time a landowner advisory committee, comprised of sixteen members, was organized. Reports and presentations have been submitted to this committee at the conclusion of each phase of the planning process for comments and guidance. A total of nine land owner advisory committee meetings have been held in Morro Bay with SCS, RCD, and Coastal Conservancy personnel from study initiation through draft plan review phases.

The project and its goals were the subject of an article published and distributed in the watershed area by the Telegram Tribune (San Luis Obispo) during the early phases of the project. Since that time, state, local, and private entities have been consulted during various phases of plan development. Some of this consultation occurred during meetings of the Morro Bay Task Force.

8.2 Coordination with Other Agencies

California Coastal Conservancy

Personnel assisted SCS in photographing active and inactive erosion scars during aerial flights over the watershed in order to develop comparative information to further interpret the results of available technical reports from private consultants. This assistance helped in the identification of new gullies and in the assessment of additional large scale erosion sources.

Morro Bay Agency Task Force

Results of SCS erosion control planning were presented before a local task force organized by San Luis Obispo County to assist in the determination of general impacts on Morro Bay. Maps, sediment volumes to the bay, alternatives for treatment, and sediment reduction from the implementation of these alternatives were presented.

City of Morro Bay Public Works

Discussions with the Public Works Director were held to discuss the city's plans for water development purposes in the Chorro Creek Watershed and how their plans might possibly incorporate a sediment basin and wetland enhancement project which may have potential for partial funding by the State Coastal Conservancy.

Philip Williams and Associates, Consultants in Hydrology

Preliminary findings of a study entitled "Sedimentation Processes in Morro Bay, California (1988)" were presented by Dr. Jeffrey Haltiner, (Principal, Philip Williams and Associates), to members of the landowner advisory and to SCS personnel. Coordination between Philip Williams and Associates and SCS made it possible to utilize data from the 1988 study to assist in the early formulation of alternatives which will contribute toward the development of an effective enhancement plan to control erosion in the Morro Bay Watershed.

8.3 Distribution List for the Draft Plan

County of San Luis Obispo:
- Supervisor Bill Coy
- Steve Earby, Associate Planner
- Ellen Rognas, Environmental Coordinator
- Connie Harms, County Schools
- Stan Saude/George Protopapas, County Engineering
- Richard Greek, County Agriculture

City of Morro Bay:
- G.H. Nichols, Public Works
- Jeff O'Dell, City Council

California Men's Colony, Carmen Salvato
California Coastal Commission, Les Sternd
Cal Poly State University:
- Dr. Tom Rice
- Dr. David Chipping
- Dr. V.L. Holland
- Dr. James Vilkitis

Bay Foundation, Don Parham
Natural History Association, Jean Cartwright
Regional Water Quality Board, Bill Leonard
Assemblyman Eric Seastrand
Senator Ken Maddy
Cuesta College, Ken Fite
State Department of Fish and Game:
- Bud Laurent
- Karen Worcester

State Department of Parks and Recreation:
- Dave Sears
- Maryanne Showers

Morro Coast Audubon Society, Phil Persons
U.S. Army Corps of Engineers, Stephen Fine
Nature Conservancy, Ken Wiley
California Conservation Corps, Tim Rochte
California Nat'l Guard, Camp San Luis, Lt. Col John Hageman
U.S. Forest Services, Los Padres Nat'l Forest, Keith Guenther
Pacific Gas & Electric, Wayne Brossard
Morro Bay Watershed Landowner Committee
San Luis Obispo Land Conservancy, John Ashbaugh
State Lands Commission, Gary Horn
Environmental Protection Agency, Suzanne Marr
Sierra Club, Dominic Perello
U.S. Fish & Wildlife Service, Brooks Harper
Water Resources Control Board, Craig Wilson
State Coastal Conservancy, Carol Arnold

9. REFERENCES

Cebula, R.J. 1974. The quality of life and migration of the elderly. The Review of Regional Studies 4(1): 62-68.

Haltiner, Jeffrey. 1988. Sedimentation processes in Morro Bay, California. Philip Williams and Associates, San Francisco.

Horton, R.E. 1945. Erosional Development of Streams and Their Drainage Basins; Hydrophysical Approach to Quantitative Morphology. Geol. Soc. America Bull. 56:275-370.

Josselyn, M. M. Martindale, and J. Callaway. 1989. Biological Resources of Morro Bay as Impacted by Watershed Development in Los Osos and Chorro Creek Watersheds. State Coastal Conservancy Report. Oakland, California.

Leedshill-Herkenhoff, Inc. 1988. Coastal stream diversion and storage project: Feasibility Study - Final Report. City of Morro Bay, California.

Parker, B. 1989. Personal Communication. California Department of Forestry.

Perspective Planning, Inc. 1988. Sweet Spring Resource Enhancement and Access Management Plan. California Coastal Conservancy. Oakland, California.

Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish and WIldlife Service Publication, FWS/OBS-84/24, U.S. Department of Interior, Washington, DC.

Pillsbury, N.H. 1979. Erosion sources in the Morro Bay Watershed. County of San Luis Obispo, Government Center.

Tetra Tech, Inc. 1975. Sand transport analysis, Morro Bay. U.S. Army Corps of Engineers Contract No. DACW-09-75-0029.

Turner, K.M. 1986. Vegetation Management for Water Supply Augmentation. Proceedings California Watershed Management Conference, November 18-20, 1986, West Sacramento, CA.

The Morro Group. 1987. Wastewater treatment facilities. Final Environmental Impact Report. County of San Luis Obispo, Government Center.

U.S.D.A./Forest Service. 1988. Final environmental impact statement: Land and Resource Management Plan. Los Padres National Forest, Goleta, California.

U.S.D.A./SCS Engineering Field Manual.

U.S.D.A./SCS National Handbook of Conservation Practices.

U.S.D.A./SCS. 1981. Soil Survey of San Luis Obispo County, Coastal Part.

U.S.D.A./SCS. 1989. Erosion and Sediment Study Morro Bay Watershed. Coastal San Luis Resource Conservation District and California Coastal Conservancy.

U.S. Department of Interior, Geological Survey. 1897. Cayucos Quadrangle Map.

Westec Services, Inc. 1988. Twin bridges replacement project. Draft/EIS Report and Evaluation. County of San Luis Obispo, Government Center.

Date: 4/29/89

TO: TOM RICE
610 10th ST., SUITE B
PASO ROBLES, CA 93446

FROM: DAVID H. CHIPPING
PHYSICS DEPT.
CAL.POLY. STATE UNIV.
SAN LUIS OBISPO, CA 93402

RE: Morro Bay Watershed Enhancement Plan and Sediment Study, Morro Bay Watershed: USDA Soil Conservation Service

Dear Tom:

1 I have a few comments on the Erosion and Sediment Study, Morro Bay Watershed. First of all, it wasn't. The document was basically a study of erosional sediment sources, and said almost nothing about sediment type, size allocation in the transportation process, and relationship of sediment size and distribution to the suggested mitigation measures.

The sediment production methods that Pillsbury and the SCS staff used are fine in producing figures of sediment production to the channel, given a very heavy rain and sheet flow. The rest of the numbers look like the result of juggling. For example, in Table E stream banks are given 90-100% SDR's, but exposed sediment in those banks are commonly gravels and cobbles of older stream deposits with a supposed SDR of 5% in Table G. There is a serious question of how much the soil grain size distribution of soils of Table F is relevant anyway, given the contribution of C-horizon and decomposed rock in both bank, deep gully, and landslide generated origin. Much of this rock is pebble sized, especially from the serpentines. Just take a look at the bed sediment in Los Osos Creek above the Los Osos Valley Rd. bridge! I don't think that this is a big thing however, and maybe the figures are sort of nearly right.

2 If you look at bedload deposits in all middle and upper reaches of major channels, they are both coarse and generally clean of very high interstitial clay fines. This certainly applies to middle and upper Chorro, Los Osos, Dairy, and Bernardo Creeks. Sediments moving through Los Osos Creek into the Bay in 1969 and 1973 were dominated by eroded Los Osos sand, and much of the sediment stuck on Eto's fields was very high albedo sand. Accretion of the flood plain in the Chorro Willows was a major sediment loss to the creeks, and is dominated by fairly clean sands. On the other hand, sediment in the Los Osos Willows was muddier sand, much of the mud being fines sheet washed from the agricultural lands that were receiving the sands further upstream. I would consider SDR's for sand in Los Osos Creek to be quite high, and higher now that the channels have been cut through the old willows. You will note the increase in

2

erosion and major headward erosion downstream of the Los Osos Willows since the channels were cut. SDR's for gravel are low, given the low gradient of the high order streams, and this can be validated from walking the channels, but gravel delivery is not a function of soil type in the watershed.

Section 9, on erosion and sediment yield at point source, is excellent in its general treatment, although there is a serious question if figure 6/7 and figure 9 are pertinent, as sediment from these areas is all sand and not entering the bay. This is not a very important contributor, according to Section 10, but may be even less important in fact.

Section 10 is good, but some discussion of the effect of fallen trees in channels comes to the conclusion that they should be removed. As this is a management option later on in the text, some words should be said in favor of jams. The blockage of a straight-as-an-arrow channel is good, as it slows sediment down and decreases bedload. Frequently small meadows are generated upstream,
3 stabilized by dogwood and willow, and these will persist. They will act as filters, which are a suggested mitigation. Streams meander.. always have.. always will, and no management at moderate cost will prevent much of this bank erosion. Clean up may create more problems, as in the removal of root balls from banks, and the bed damage caused by the machinery and crew.

Sections 12 & 13 lets the guys get out their handbook and have fun. I have noticed that bank tread-down by cattle is a problem too, but worry if fence will be a problem with blocking game access to water.

Section 14 is again good, although I have no way of validating their spreadsheet values. I like all the revegetation suggestions,
4 provided there is also some botanical sensitivity and we don't turn the creeks into BOTANY FROM HELL. In other word, don't use all the wrong grasses like every federal revegie project of the past.

The snow pea idea won't work, as the farmers orient their rows with the sun. Anyway, all the major rain events take place in January and February when most everything is either bare or just sprouting, and the preliminary plough is usually O.K.

The section j on urban is well noted, but should not be worth making a political issue in Los Osos, as almost no sediment makes it to the Bay. I can generally validate this.

The whole sediment basin idea is here given a mixed review. I love the idea of large basins just above the bay entry points, and hate the concept of upper elevation basins. Take, for example, the sediment fans above the Cuesta -CMC reservoir. They are very, very
5 coarse deposits of fast and flashy floods. This is not material that is generally going to go far down the channels, and will resemble material entering sites 2-5 of figure 6, Enhancement Plan. This will do little to strain out the fines, do to high in-basin

turbulence during bypass, will produce a significant sediment disposal problem, and will do serious harm to riperian zones and to surrounding habitats. (We have 7 or 8 listed plants in these areas). In addition, the bedload-deprived water bypassing the basins will gain sediment carrying capacity, increasing channel and bank erosion downstream. This will provide zero gain for a lot of pain.

5 The Chorro Creek site 6 is good, provided I am thinking the same as you guys. I would envision less of a hole in the ground and more of an extension of the willows, coupled with removal of the bordering diversion levee and the development of a dispersal distributary system upstream of de dark woods. If you just want a big hole in the ground you will be below water table much of the year, will possibly do ugly things to the Morro Bay water wells, and might suffer other complications, and therefore a little more description of the intended basin idea is MUCH needed. A small problem of backwater will develop whatever you do, so think wet houses in the middle and upper Chorro plains when you do an engineering model.

Warden Lake is perhaps not worth the bother. The 60 inch culvert already causes the lake to fill, and water backs up to well within site of Los Osos Valley road in the 2-yr flood (or so). The lake bed is full of fines, and the flat valley floor upstream and the wierd channellized streamlets crossing the ranches allow in-channel
6 sedimentation to take place. Turri Ranch is always playing patticake with a dragline due to in-channel siltation. All the significant sediment comes from Los Osos Creek. A more effective dispersal would be to remove the through channels in the Los Osos Willows, fill Turri Road to above flood grade, and use to Willows as a sediment trap like they used to be. Buy some land at the Los Osos- Warden confluence, and put in more riperian vegies. On the other hand, entrance turbulence to a planned lagoon at Warden would be low, and fines entrapment would be somewhat increased, but it is really a question of how cost effective this would be.

In regard to the basin analysis, what is going on in Appendix C? What is the justification of a 10% partition factor between Column 3 and Column 6 in the spreadsheet. Are you assuming exactly identical sediment production relative to size distribution from all sources in Column 1?. Are we to believe that sediment from the banks of a
7 rapidly gullying Order 2 stream will be identical to that from a snow pea field relative to partition efficiency of the reservoir? No way! Even more incredible is the partition of 10% applied to all of the basins, including steep gradient basins such as San Luisito and Pennington. Warden and Pennington lie in totally different energy zones, with completely different sediment size distributions. As this appears to be a main factor in regard to cost efficiency calculations, the whole section should be reevaluated.

Appendix A looks good, and would reflect SCS experience relative to general conservation cost efficiency. Good stuff.

Well, Tom... that brings me to the end of direct comment on the

documents, and as you can see, I think they need a little work. A comment or two on the philosophy behind this approach might be in order.

Obviously anything that SCS and the Conservation District can do to implement normal conservation practice must be of help to the watershed, and the costing work calculated in the documents appears to be sound, although out of my province. However the pattern of sedimentation into the bay cannot be calculated on the basis of cumulative annual events, where the normal event is the average event. The giant floods probably bring in 90% of the sediment delivered within a 50-yr interval, mainly in the space of two weeks. You will remember that the oyster beds at Grassy Island where covered with 2 feet of slit in 1973 in a single event. You guys must therefore concentrate on how creek bed modifications will 8 intercept the upper bound discharge event, and especially on the efficiency of capture of silt and flocculateable clay fractions that will be bound for the back tidal flats on the inbound tide. It is my opinion that basins will work less efficiently than a heavily vegetated riperian zone such as Chorro Willows, but that fines bypassing will take place in very great volume. The trees will do a wonderful job of removing bed and saltation load, and in addition will increase upstream base level aggradation on the flood plain, but also increase upstream flood stage. A small sediment basin will be filled quickly. Before anybody commits to a basin purchase, please answer the questions relative to sediment entrapment efficiency for large events compared to riperian filters, the amount of fines bypassing, the impacts on backwater, and the availability of sediment disposal sites for basin cleaning.

There may be some other considerations that will complicate life, such as water diversion projects on the Chorro watershed. If these go through, the value of upstream sediment basins might increase relative to protection of downstream diversion in normal years. There might even be an opportunity to combine functions.

Sorry this is all a little rushed but your postcard reminder arrived a few days before comments were due, (Thanks!) and I zapped this together.

All the best

David Chipping