Northern Salinas Valley Watershed Restoration Plan:

Final Report of AMBAG's Water Quality Planning Project Entitled

Nonpoint Source Pollution in Coastal Harbors & Sloughs of the Monterey Bay Region: Problem Assessment & Best Management Practices

FINAL REPORT

January 1997

This project has been funded wholly or in part by the United States Environmental Protection Agency Assistance Agreement No. C6999214-95-0 to the State Water Resources Control Board and by contract No. 4-134-250-0 in the amount of $92,500.00. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Nonpoint Source Pollution in Coastal
Harbors and Sloughs of the Monterey Bay Region

Acknowledgements

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USDA Natural Resources Conservation Service (former Soil Conservation Service)
U.S. Army Corps of Engineers
NOAA - Monterey Bay National Marine Sanctuary
Elkhorn Slough National Estuarine Research Reserve

State Water Resources Control Board
Central Coast Regional Water Quality Control Board
California Department of Fish and Game
California Coastal Commission - Central Coast Office
State Mussel Watch Program

County of Monterey (Environmental Health, Planning, & Public Works Depts.)
Monterey County Water Resources Agency
Monterey County Agricultural Commissioner
City of Salinas (Public Works & Planning Depts.)
Monterey County Resource Conservation District
Moss Landing Harbor District

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Central Coast Agricultural Task Force
Sierra Club - Ventana Chapter
California Native Plant Society - Monterey County
Monterey Bay Aquarium Research Institute
Save Our Shores
Elkhorn Slough Foundation
Center for Natural Lands Conservation
Return of the Natives Education/Outreach Program
Artichoke Advisory Board
Sea Mist Farms (major land holder and farming interest in the watershed)

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Northern Salinas Valley Watershed Restoration Plan

1. Executive Summary

This is the final report for a project entitled *Nonpoint Source Pollution in Coastal Harbors and Sloughs: Problem Assessment and Best Management Practices.* This report has been prepared for the Association of Monterey Bay Area Governments (AMBAG) by the Moss Landing Marine Laboratories (MLML), working in conjunction with the Watershed Institute of California State University at Monterey Bay (CSUMB). This project has been funded under section 205(j) of the federal Clean Water Act, which provides funding for studies that plan for the remediation of polluted runoff and other types of nonpoint source water pollution.

The primary goal of this project has been to develop an adaptive water quality management plan for the northern Salinas Valley watershed. This drainage basin includes all of the water courses that flow from the Gabilan Mountains, east of Salinas, into Moss Landing Harbor from the south -- Gabilan, Natividad and Alisal Creeks, and the their associated sloughs and drainage ditches, particularly Tembladero and Moro Cojo Sloughs (see Figure 5).

The primary water quality improvement method proposed here is the restoration of former wetland and riparian areas -- termed "wet corridors" -- throughout the target watershed. Most of the former wet corridor areas in the Salinas Valley were transformed into farm fields and drainage ditches in the early 1900's. The restoration of these former wet corridors improves the water quality of downstream water courses (Hammer and Bastian 1989, Gearhart 1992). Wetlands and riparian areas act as natural sediment and pollutant filters (Hupp et al. 1993, Puckett et al. 1993, Mitsch and Gosselink 1993). In these wet environments, plants can sequester pollutants in their tissues, and microbial action can break the pollutants down into harmless substances (Hammer and Bastian 1989, Mitsch and Gosselink 1993). Wetland and riparian corridor restoration can be accomplished through the establishment of Water Management Areas (WMAs) -- ecologically engineered impoundment sites that allow for the re-establishment of native wetland/riparian vegetation. In addition to improving water quality, wet corridor restoration can also improve groundwater recharge, decrease flood water levels downstream, increase critical habitat area for many threatened or endangered species, and even decrease wildfire danger by providing moist firebreaks (National Research Council 1992).

This report addresses all relevant aspects of wet corridor restoration, including the various benefits of restoration, technical approaches to restoration, long-term restoration monitoring, ongoing local restoration demonstration projects, the issues surrounding obtaining landowner permission to conduct restoration activities, public education, and the uncertainties and barriers to successful wet corridor restoration that still need to be addressed.

Salinas Valley's Water Quality and Supply Problems: The northern Salinas Valley's water quality problems are significant and well documented, ranging from groundwater contamination by nitrates and seawater intrusion, to surface water contamination from agricultural chemicals and to a lesser extent urban runoff. Some of the highest levels of surface water pesticide contamination found statewide by the State Mussel Watch and Toxic Substances Monitoring Programs have been found in the northern Salinas Valley -- including extremely high levels of the toxic and persistent pesticide DDT and its breakdown products.

The Salinas Valley has been dramatically modified by over 100 years of intensive agricultural activity, and more recent urban and suburban development (Gordon 1996). Over 90% of the Valley's freshwater wetlands including lakes, rivers, marshes, and riparian areas have been transformed into farm fields, drainage ditches and urban development (Gordon 1996). The decrease in the amount of wet corridor/groundwater recharge area, in combination with unsustainable rates of groundwater pumping for irrigation, has led to the Valley's serious water resource problems -- including seawater intrusion into fresh water aquifers, degraded surface water quality, higher floodwater levels, and a great reduction in wetland/riparian habitat which was once home to many now locally extinct or endangered species (Gordon 1996).

Technical Approach to Wet Corridor Restoration: The historical natural setting provides baseline guidance for choosing restoration sites and plans. Due to hydrologic and edaphic conditions, it is easier to create vegetated wet corridors on sites where they previously existed. The historical wet corridors were mapped in the northern valley to provide this baseline. Anthropogenic constraints such as roads, private properties, and dams are superimposed upon this natural setting, further limiting the number of potential restoration sites.

The first field task is to gain landowner participation in the restoration, and therefore access to a site. A restoration and monitoring plan should consider the need for erosion control, land form changes (e.g., grading and berm construction), surface water retention, non-native plant control, and native plant re-establishment. Progress is monitored to evaluate restoration success including photographs from airplane, helium balloon, and permanent ground stations. Common measurements include plant survival and growth, surface water nitrate and turbidity, and qualitative biodiversity surveys.

Demonstration Projects: The Watershed Institute has initiated demonstration wet corridor restoration projects throughout the Monterey Bay area, with the Moro Cojo Slough vicinity a major target area. Moro Cojo Slough is the focus of many public agency protection and restoration efforts. Ongoing wet corridor restoration project sites are located at the Moon Glow Dairy marsh, Castroville Slough, southern Moro Cojo Slough, and mid-Moro Cojo Slough, and involve over six landowners. Incentives are being developed and presented to other landowners to encourage them to permit restoration on other key parcels.

Landowner Participation: Obtaining landowner participation in wet corridor restoration is one of the most significant barriers to watershed restoration in the Salinas Valley. The Watershed Institute and one of its partners, Sustainable Conservation, have developed and begun to implement incentives for private landowners to encourage their participation in wet corridor restoration and protection (see Appendix 6).

Public Education: Public education is a prerequisite to gaining public support for watershed restoration and management over the long term. The Watershed Institute's *Return of the Natives* (RON) restoration education program has been instrumental in involving K-12 and college students, teachers, and other community members in restoration of their local environments. In the past year, over one thousand students, teachers, and members of the public have participated in RON restoration days. RON has given environmental education training to numerous teachers, has sponsored CSUMB community mentors through the Services Learning Program, has designed and built a Children's Discovery Garden at Natividad Park in Salinas, and has built greenhouses for native plant propagation at local schools, among other accomplishments. RON's activities will continue to be an integral part of the Watershed Institute's goals, and will provide labor for planting events associated with various restoration projects.

Uncertainties and Barriers: Significant barriers to wet corridor restoration include lack of access to restorable lands (i.e., no landowner permission), regulatory disincentives and a lack of positive incentives to landowner participation, and lack of public support. Landowner participation is the most important step in restoration and is improving through demonstration projects in more and more neighborhoods. The best ambassadors for restoration are neighbors and school children. Regulatory disincentives to landowner participation have become a major agency focus. However, there are few positive incentives for landowner participation such as tax benefits (federal, state or local) and easement purchase programs. Public education about watershed restoration has improved at the fastest rate from school and community groups to government. Salinas Valley and the Monterey Bay area are unique in the state. Water drainage ways are highly degraded and so are all water resource benefits; but here, unlike most other seriously degraded watersheds in the state, the wet corridors can be restored.

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2. Introduction

2.1 Major Water Problems in the Salinas Valley: Poor Water Quality and Inadequate Water Supply

The Salinas Valley is the largest watershed in the Monterey Bay area and also the most degraded by human activities (Gordon 1996). Its water quality is among the most degraded of any watershed in the state, of those not covered with concrete and asphalt (Gordon 1996). The historical creeks and rivers generally flowed with clear water, except during extreme events such as floods following large fires. The exception is now the rule. Almost all water flowing through the valley's wet corridors is laden with sediment, from the surrounding hillsides into the valley floor (Gordon 1996). High levels of nitrates contaminate surface and groundwater. Over a decade ago, the State Mussel Watch program documented some of the highest levels of pesticides in surface waters from throughout the state (e.g., Appendix 1).

The Salinas Valley is facing a severe lack of water, caused by two major processes. The first is decades of over-pumping water supply wells which is the primary cause of the extensive salt water intrusion into bay area aquifers (Greene 1970, Johnson 1983, Figure 1). The second process is the gradual shifting of the wet landscape towards desert, a common problem in most warm temperate climates with the growth of human populations (Warner and Hendrix 1984, National Research Council 1992, Mitsch and Gosselink 1993, Barbour et al. 1993, Runnels 1995, Cohen 1995, Gordon 1996). The first survey of the bay area by the Coast and Geodetic Survey in 1853 described a remarkably wet landscape (Gordon 1996). Artesian springs flowed all year long at Moss Landing where the entire town drew water from a 9 foot well into the early part of this century (ABA Consultants 1989, Gordon 1996). The movement of water from the land to the sea was radically modified by early drainage channels (Figures 1 and 2), which were developed by the 1880's (Lydon 1985). Water is now drained into channels through farms and towns, into central collecting channels, that were once magnificent creeks (Gordon 1996), into the Salinas River, which is now confined in a flood control channel, and finally into Monterey Bay.

Dozens of creeks were converted long ago to devegetated ditches in an effort to drain the landscape for farming, grazing, and other human land uses (Gordon 1996, also see Appendix 2). Thousands of acres of wetlands were ditched and dried (Gordon 1996, Figures 1-3), reducing flood and natural water quality control, and reducing the natural capacity of the landscape to recharge underground aquifers. Most of the wetland landscape is now gone (Gordon 1996). Compare Figures 1 and 3.

2.2 A Solution: the Wetland Sponge

Naturally vegetated rivers, creeks, and marshes are one of the best water pollution filters known (Hammer and Bastian 1989, Gearheart 1992, Hupp et al. 1993, Puckett et al. 1993, Mitsch and Gosselink 1993). Wetland vegetation and associated habitat combine to create a thick biological sponge which physically filters sediment and organic-mineral aggregates from surface water (Mitsch and Gosselink 1993). The high surface areas of these small, complex particles are active binding sites for many of the chemical contaminants from the watershed (Hammer and Bastian 1989, Mitsch and Gosselink 1993). As a result, the levels of these chemicals are often highest on suspended particulate matter and dissolved in much lower concentrations in the surrounding water (Hammer and Bastian 1989, Mitsch and Gosselink 1993). Suspended particles are physically trapped by the vegetation. The filter is also biologically active at capturing and degrading chemical contaminants. Microorganisms live on plant surfaces and especially on and in the sediment. These biochemical factories capture, degrade, and recycle many chemicals (Hammer and Bastian 1989, Mitsch and Gosselink 1993). Dissolved chemicals are also captured by the biological filter. For example, nutrients such as nitrogen are used directly by the living plants. The overall result is considerable improvement to water quality (National Research Council 1992).

Equally important, the wetland sponge is critical for surface water retention, ground water recharge, flood protection, and biodiversity (National Research Council 1992). Along with water quality improvement, these are the major water resource values essential to a sustainable watershed for the present and growing human population.

2.3 Plan for Salinas Valley Watershed Restoration

Watershed restoration is an important component of a comprehensive watershed management plan for the Salinas Valley; it is the primary focus of this plan. This watershed restoration plan was developed for the Central Coast Regional Water Quality Control Board, the State Water Resources Control Board, the U.S. Environmental Protection Agency, and the U.S. Department of Defense. This plan can also guide the watershed restoration and mitigation activities for the Salinas Valley Basin Management Plan being prepared by the Monterey County Water Resources Agency. This plan will serve as the foundation for a Coordinated Resource Management and Planning (CRMP) effort at the Watershed Institute involving the entire Working Group of the Institute, which includes the State Department of Fish and Game, State Coastal Conservancy, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and the Monterey Bay National Marine Sanctuary. This plan is an extension of the Elkhorn Slough and Moro Cojo Wetland Management Plans and is therefore consistent with Monterey County's Local Coastal Program approved

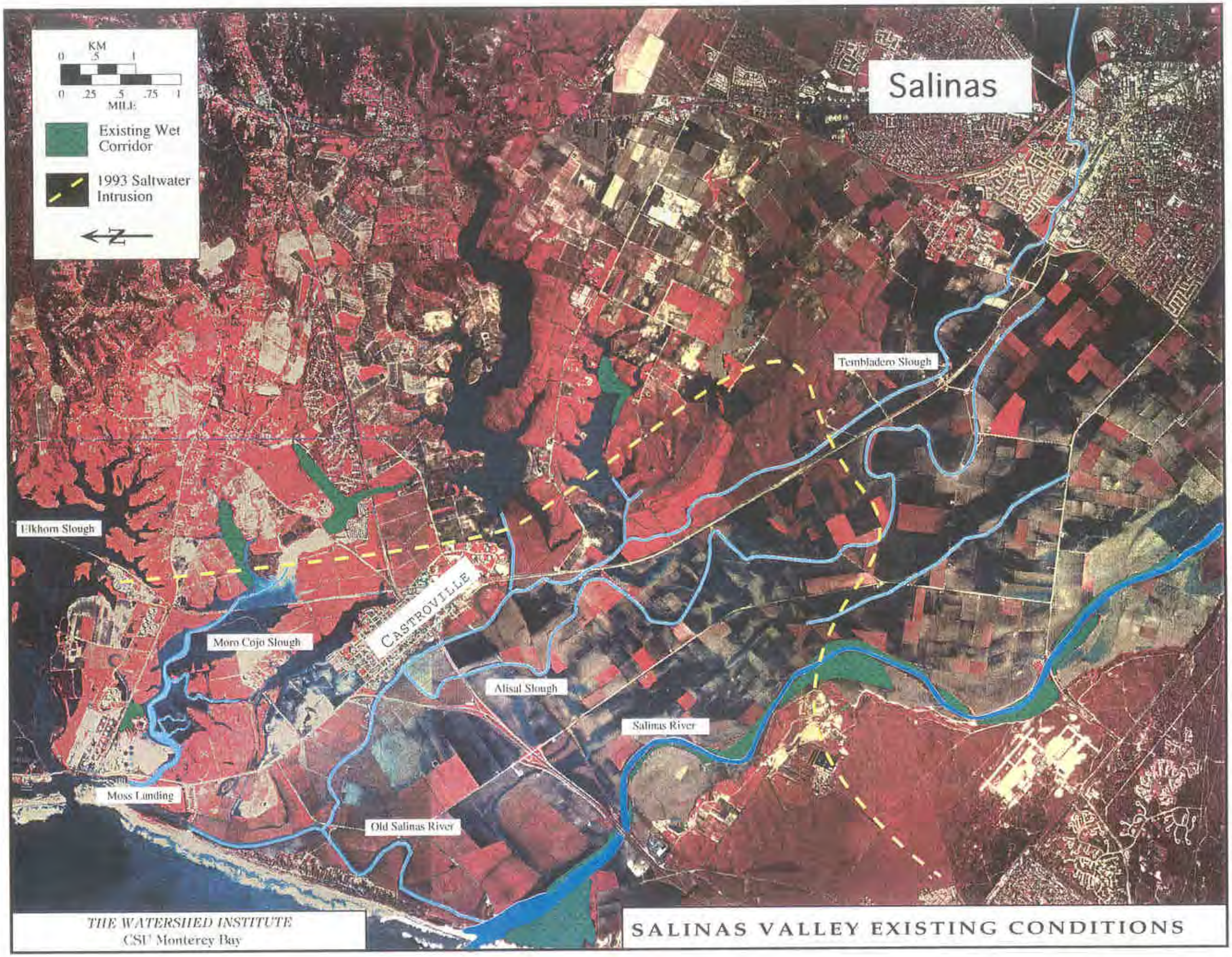


Figure 1. Existing environmental conditions in the lower Salinas Valley.

Figure 2. Tembladero Slough is a 100 year old straight, drainage channel and was a major meandering creek with steelhead and salmon runs.

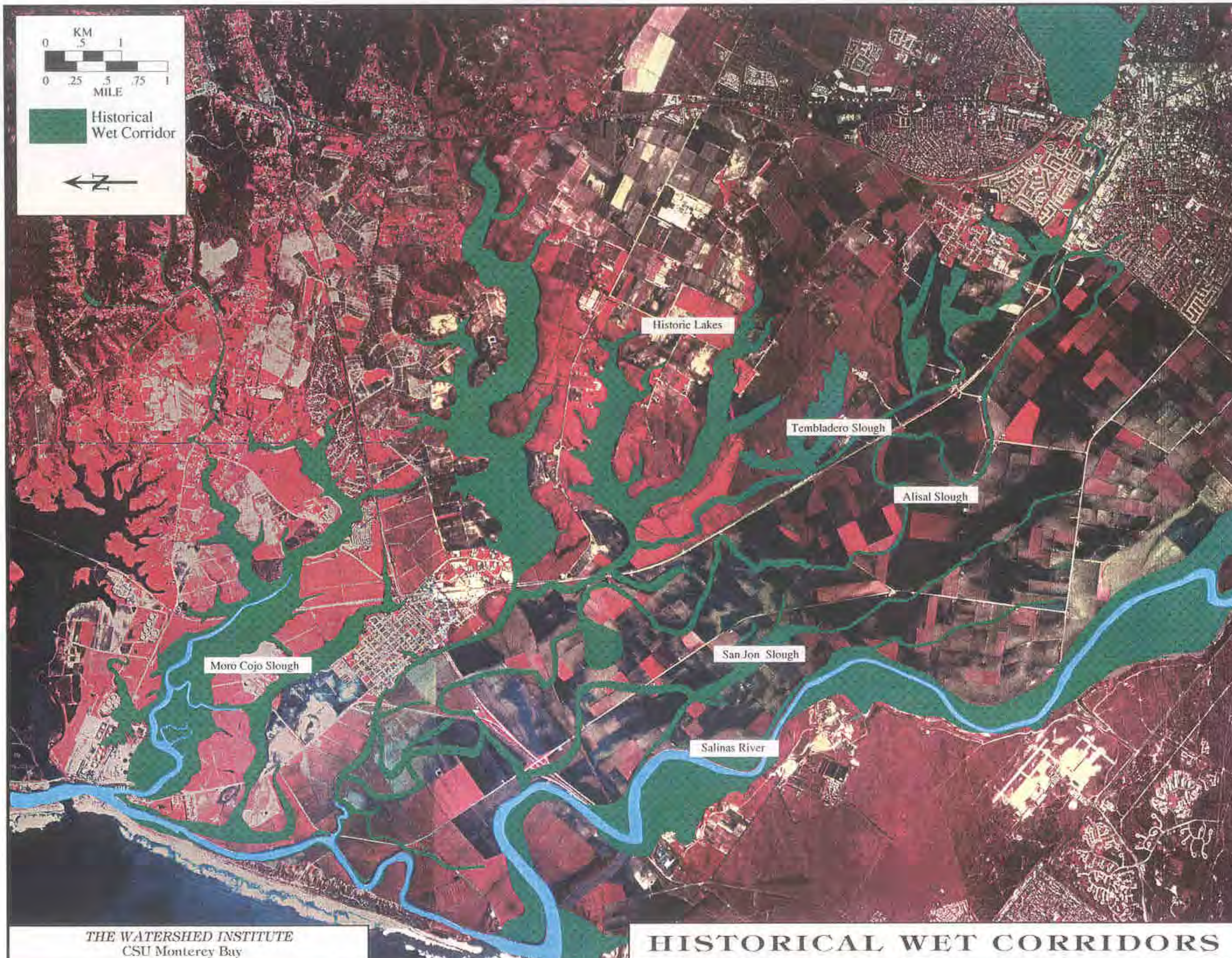


Figure 3. Historical environmental conditions in the lower Salinas Valley, near 1850.

by the California Coastal Commission, as well as Monterey County's General Plan.

This plan was developed with a companion 319(h) grant project, which is a funded demonstration project involving the use of water management areas for filtering non-point source pollution, primarily in the Moro Cojo watershed. The 319(h) project is for implementation of WMA's and monitoring their success. This 205(j) plan uses the 319(h) project results to provide more realistic descriptions of water management areas.

3. Benefits of Wet Corridor Restoration to Local Water Problems

An important and ecologically sustainable long-term solution to water resource management is watershed restoration, focusing first on the restoration of wet corridors. Wet corridor restoration is a key "best management practice" for restoring and protecting all water resources (National Research Council 1992, Mitsch and Gosselink 1993). Restored wet corridors are recognized "Water Management Areas" by the State and Regional Water Quality Control Boards, permitting their use to filter sediment and chemicals from drainage water and to retain water for irrigation.

In the Salinas Valley, restored wet corridors have great potential to:

1) increase surface water retention;
2) improve ground water recharge (and concurrently help to reduce sea water intrusion into fresh water aquifers);
3) increase levels of flood protection due to enhanced flood storage capacity;
4) improve water quality due to the recovery of natural vegetation and habitats that filter runoff from farm and urban land;
5) increase biodiversity due to habitat enhancement; and
6) increase fire protection via wet corridor barriers.

Primary wet corridors include the creeks, rivers and low marshes that form the major natural drainage ways of the valley. Their locations, general dimensions, and barriers to flood retreat were clearly identified during the major flood of 1995 (Watershed Institute 1995).

Local wet corridor restoration is highly feasible and relatively inexpensive, as the demonstration projects at the Watershed Institute have shown (Section 6). Restoration includes widening existing artificial drainage ditches into a more natural configuration, spreading water over low ground, and planting these newly created wet areas with native riparian and other wetland vegetation. Farmland and other human development on the adjacent flood plain can be protected from flooding by constructing ecologically engineered berms: low slope dikes covered with appropriate native vegetation. On grazing lands, the wet corridors can be restored through a similar process, except that the wet corridors must also be fenced to exclude large grazers such as cattle. The fenced area generally will amount to only a small proportion of the land area of most ranches, yet will yield high returns for water resources.

3.1 Improved Water Quality

The worst water quality problems in the Monterey Bay area and the state are caused by non-point source pollution from farm and urban drainage systems (Ladd et al. 1984, Watkins et al. 1984). The solution proposed here is to filter drainage water through a naturally vegetated wet corridor with many retention ponds, located along the wet corridors shown in Figure 4. This is a general solution relevant to many other watersheds (Mitsch and Gosselink 1993). This vegetated habitat physically and biologically filters water, removing sediment and chemical pollutants from the water column (Hammer and Bastian 1989). In contrast, the existing ditch system without vegetation transports muddy, contaminated water directly into the ocean and marine sanctuary. The wetland biological filter is well known for its ability to dilute, filter, retain, and biologically degrade toxic chemicals (Hammer and Bastian 1989, Gearheart 1992, Hupp et al. 1993, Puckett et al. 1993, Mitsch and Gosselink 1993). By the time the vegetation is several feet high, it forms an effective physical barrier to the transport of eroded soil.

The primary sources of chemical contaminants to water quality are from storm drainage off urban landscapes and fertilizers, pesticides, and herbicides used on farm lands. The major farm and urban regions of the lower valley are easily distinguished from aerial photographs (Figure 1). The main watershed sinks for these chemicals are sediments in the flood control channel system, especially the Moss Landing Harbor, Old Salinas River, and the Salinas River lagoon (Figure 1). These patterns were observed during years of sampling waterways in the lower valley done primarily by the State Mussel Watch program (see data in Appendix 1) as well as during our qualitative ecological surveys of the same wet areas (Appendix 2). The most contaminated sink is the south end of Moss Landing Harbor (Appendix 1). The plan presented here is a viable long-term solution to reducing chemical inputs to this sink (for example, Hammer and Bastian 1989, Gearheart 1992, Hupp et al. 1993, Puckett et al. 1993). The more immediate management problems and solutions for sediment contamination in the harbor are presented in Appendix 1.

Erosion control actions, such as sediment retention ponds, on or near farms and heavily grazed land are important best management practices for improving water quality and protecting wet corridors.

3.2 Enhanced Water Retention and Recharge

Restored wet corridors can increase the rate of ground water recharge, thus putting positive pressure on fresh water aquifers to push against intruding sea water, protecting the aquifers from further salt water intrusion (National

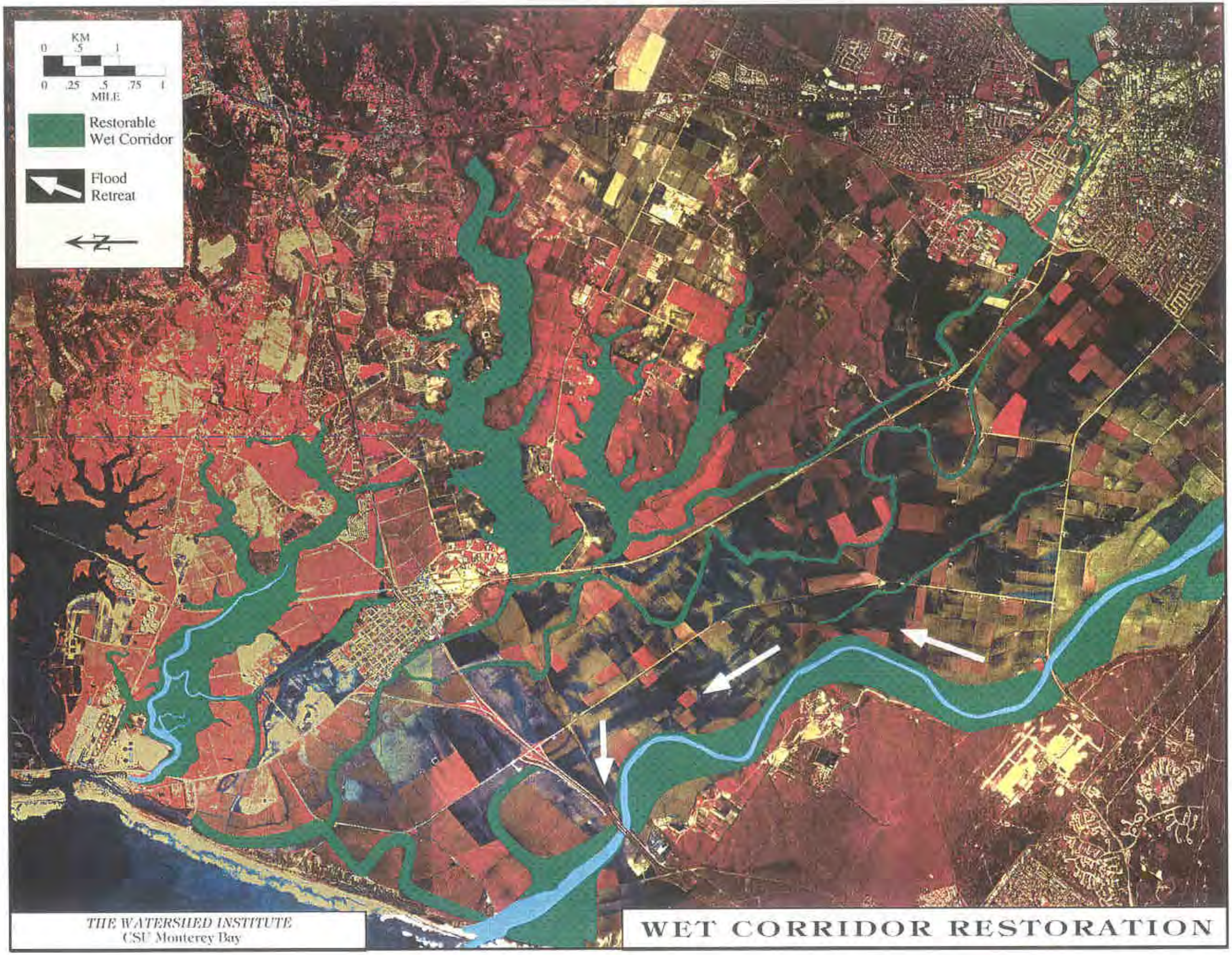


Figure 4. Potential wet corridor restoration sites in the lower Salinas Valley.

Research Council 1992, Mitsch and Gosselink 1993). The opportunity for downward movement of water into deeper aquifers is high along the natural wet corridors, where water flow has cut through a wide variety of sediments and rocks at every elevation in the watershed. The ground below the corridor is a sponge with vertical and horizontal changes in permeability including potential cracks caused by the frequent and intense tectonic activity along the coast (National Research Council 1992, Mitsch and Gosselink 1993). With positive pressure from the surface, the deeper sponge absorbs water. Because less permeable formations may prevent or slow vertical movement between aquifers, the relation between aquifer recharge and the flow and retention of surface water is complex. Water can flow much more rapidly in layers of sand and gravel, while it may take many decades to re-saturate thick layers of peat or clay and silt deposits that were drained and dried long ago. If these deposits are made wet again, there will be a much greater volume of water in the watershed and an increase in the local and regional water downward pressure. The resulting "curtain" of ground water is like a dam holding water at higher and higher elevations in the watershed, keeping upper watershed water courses wetter for longer periods (National Research Council 1992).

Surface water can also be stored along all wet corridors in ecologically engineered ponds, similar to the scale of those constructed by beavers and farmers. This water can be drawn down to a pre-determined minimum elevation and used for irrigation. The minimum elevation would be enough to sustain a healthy wet corridor for other water resource values (water quality enhancement, biodiversity, erosion control, flood protection, and fire breaks). At some locations, the ponds would be dry for part of the season, naturally and with early draw down for human uses.

3.3 Increased Flood Protection

The Salinas Valley's channel system was constructed primarily to reclaim land for farming, grazing, and eventually other land uses. Over time these channels became the flood control system, similar to many other watersheds around the world (National Research Council 1992). Now the channel system must be dredged for flood control, thus maintaining the existing ditch system configuration and surrounding land uses. Unfortunately, the most limiting natural resource in the region, water, is drained rapidly into the ocean by this ditch system.

Viable flood protection can be obtained from widening the wet corridors from the coast into the hills, replanting native plants throughout, and constructing ecologically engineered berms to keep water from sensitive flood plain areas (National Research Council 1992, Mitsch and Gosselink 1993). Restored wet corridors will increase the flood storage capacity of the landscape by holding a larger volume of water for a longer residence time. Overflow from the wet corridors can be directed through low flood ways to minimize flood damage and facilitate flood retreat (Figure 4; Watershed Institute 1995).

3.4 Enhanced Biodiversity

Monterey Bay is located in the center of one of the most important biodiversity hot spots in the world (Wilson 1993). This region harbors one of largest concentrations of species in the temperate world (Wilson 1993). The restoration of wet corridors in the Monterey Bay area will increase local and regional biodiversity as much as any positive ecological action that can be taken. First, because freshwater habitats are among the most endangered ecosystems in the region: over 90% have been eliminated from the Salinas Valley (Gordon 1996). They harbor the most endangered group of animals on the planet, amphibians (Jones and Stokes 1987, Wilson 1993), and many other groups of special concern which benefit from retaining water along wet corridors. Like humans, other animals need water and will directly benefit from greater availability of water along naturally functioning wet corridors (Mitsch and Gosselink 1993).

3.5 Increased Fire Protection

Wet landscapes and associated vegetation are generally difficult to burn. The plants are usually green, poor fuel, and the ground is wet. Therefore, wet corridors can make excellent fire breaks, separating areas of more combustible landscapes. This can be important in rural residential areas where dry vegetation in open space is adjacent to homes. Some natural habitats and plant communities are well adapted to fire and burn easily and explosively, such as chaparral, grasslands, and pine forests. Non-native weeds can also be extremely flammable and are thus the target of intense fire control activities. However, fires can be stopped and slowed at wet corridors, which may become more important as the landscape continues to transform towards urban development and arid conditions.

4. Development of Watershed Restoration Plan

The best model for habitat restoration is the historical natural ecosystem, especially the wet corridors where water carved natural courses over very long periods of time (National Research Council 1992). The historical wet corridors of the lower Salinas Valley included a broad riparian corridor with low marshes along the Salinas River; old channels of the river harboring dense marshes like San Jon Slough (Blanco Drain area) and Alisal Slough; and a series of lakes, marshes, and riparian habitats along the low hills from Moro Cojo Slough into the City of Salinas. The Tembladero Slough connected most of these lakes and was a large creek with salmon and steelhead runs into many tributaries (Gordon 1996, see Figure 2). This wet landscape was ditched and drained many decades ago (Gordon 1996, see Figure 1).

The location of the historical wet corridors can be predicted accurately (Figure 3), but the past wildlife habitats are much more difficult to reconstruct (Gordon 1996). The location of wet corridors is primarily determined by topography, hydrology and soils, which are inter-related. The ecological communities which inhabited the historical wet corridors are only known from general descriptions and from small habitat remnants which still survive today (Gordon 1996). In addition, there are a number of less disturbed wet corridors along the central California coast that harbor well-developed wildlife habitats and can be used to reconstruct possible ecological communities for the highly modified watersheds of the Salinas Valley.

The restoration plan for these wet corridors must work within the physical constraints of the existing conditions in the valley (Figure 1). These constraints are primarily related to landform and drainage changes from human land use patterns, especially the highways and roads and regions of urban development. The location of farm land in the flood plain is also an important constraint. The restoration model proposed in Figure 4 is an attempt to recover the most important parts of the historical wet corridors to maximize all water resource values. The plan includes the restoration of existing farm land along most of the major drainage ways and in the largest historical lakes (Figure 4). This restoration plan cannot be implemented without the permission of land owners, and thus depends on developing the landowner incentives discussed in section 5.1. However, the plan can be implemented parcel by parcel (Figure 5): restoration of any section of the wet corridor improves all water resources. Landowner incentives for restoration are already working much better on lands with the lowest economic value. For this reason, the restoration plan first targets the wet grazing and fallow farm land in the Moro Cojo Slough (Figure 6) and secondarily the riparian corridors draining grazing land along the valley hillsides (Figure 5). No implementation can proceed without landowner permission. Until new landowner incentives are developed or existing incentives modified, the Watershed Institute will continue its present programs to develop agency and landowner partnerships to restore wet corridors as water management areas. When future landowner incentives have been developed, the costs can be estimated from demonstration projects (Section 4).

5. MAJOR RESTORATION TASKS

The first and most important implementation task is gaining permission to restore the wet corridor on a particular parcel of land. The next tasks involve the field restoration activities and include making changes in land forms and hydrology (e.g., grading and berm construction), non-native plant control, and native plant establishment.

Every restoration is a large-scale experiment with the potential for a variety of smaller-scale experiments within each site. The most important measure of success is to begin the restoration. The next is to follow through, learning from the natural development of wet habitats and ecological communities. Most of the past and current discussion of restoration failures concerns the failure of habitat restoration done through the permit process, where mitigation measures are required for development projects (Zedler 1996). In the mitigation process, land owners often feel like victims of the permit process and not like partners in restoration. It is difficult to achieve successful restoration without this partnership. The major reason for past failures in the Salinas Valley is the lack of follow through because of ineffective enforcement or monitoring, and especially because the landowner is not a willing partner. Although restoration success can be improved by making more realistic objectives and monitoring each site for success (Zedler 1996), the development of genuine restoration partnerships is likely to have a much greater positive impact.

Future landowner incentive programs are likely to require the largest public investment. The cost of public purchase of land or easements is much higher than the cost of land form changes, erosion control, non-native plant control, and native plant establishment. These field restoration costs will vary considerably from project to project, but can be developed for a particular site.

5.1 Landowner Participation

Obtaining permission to restore wet corridors on private land is a significant barrier to implementation of watershed restoration in the Salinas Valley (Dwyer 1996, Appendix 6). We have obtained excellent access to public lands primarily through the use of demonstration projects, as examples. Access to private lands and other barriers can be overcome partly through the same process, demonstration projects in more and more neighborhoods, and through other pubic education. Efforts such as the Return of the Natives project, a community education program for watershed restoration, is described in Section 10.

Many landowners of the Salinas Valley are aware of the local and regional water problems and the need to hold water in the watershed as one of the solutions to those problems. Simple, realistic, and effective solutions to the existing ground water, water reuse, and water quality problems are a primary incentive to making private land wetter. As future water supplies become more limited in the Salinas Valley, any land which holds water will likely increase in value. In the meantime, other landowner incentives for wet corridor restoration will be needed. These will likely include public purchase of easements for flood control and ground water recharge, and programs for reducing income and property taxes of participants (see Appendix 6). Some tax incentive programs are already available and can be used now if the water value of the land could be used in the appraisal process.

Disincentives to restoration should be removed: they are perhaps best developed in the policies of regulatory agencies. For example, the concept of a "safe harbor"

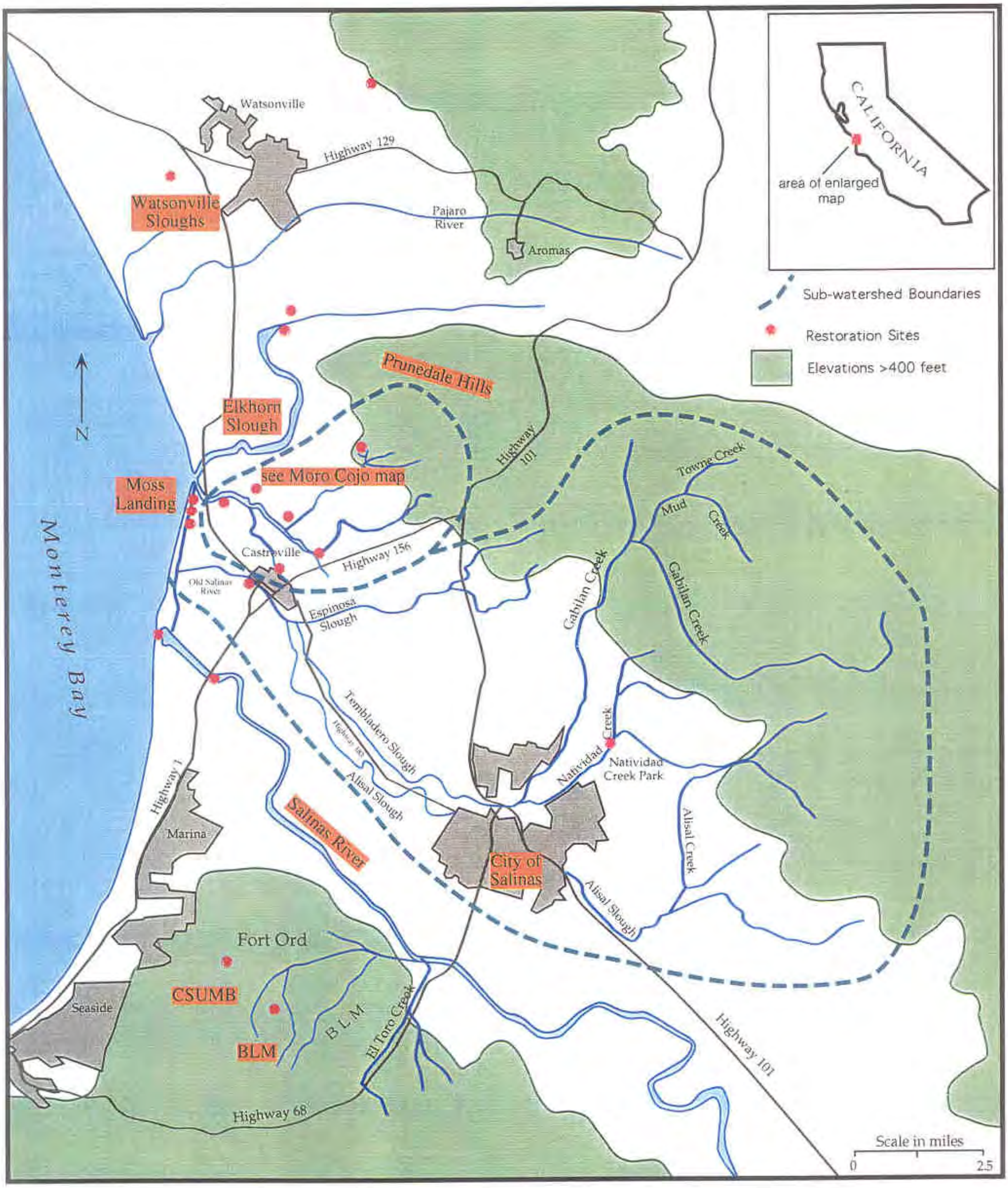


Figure 5: Location of Watershed Institute restoration sites in the Monterey Bay area.

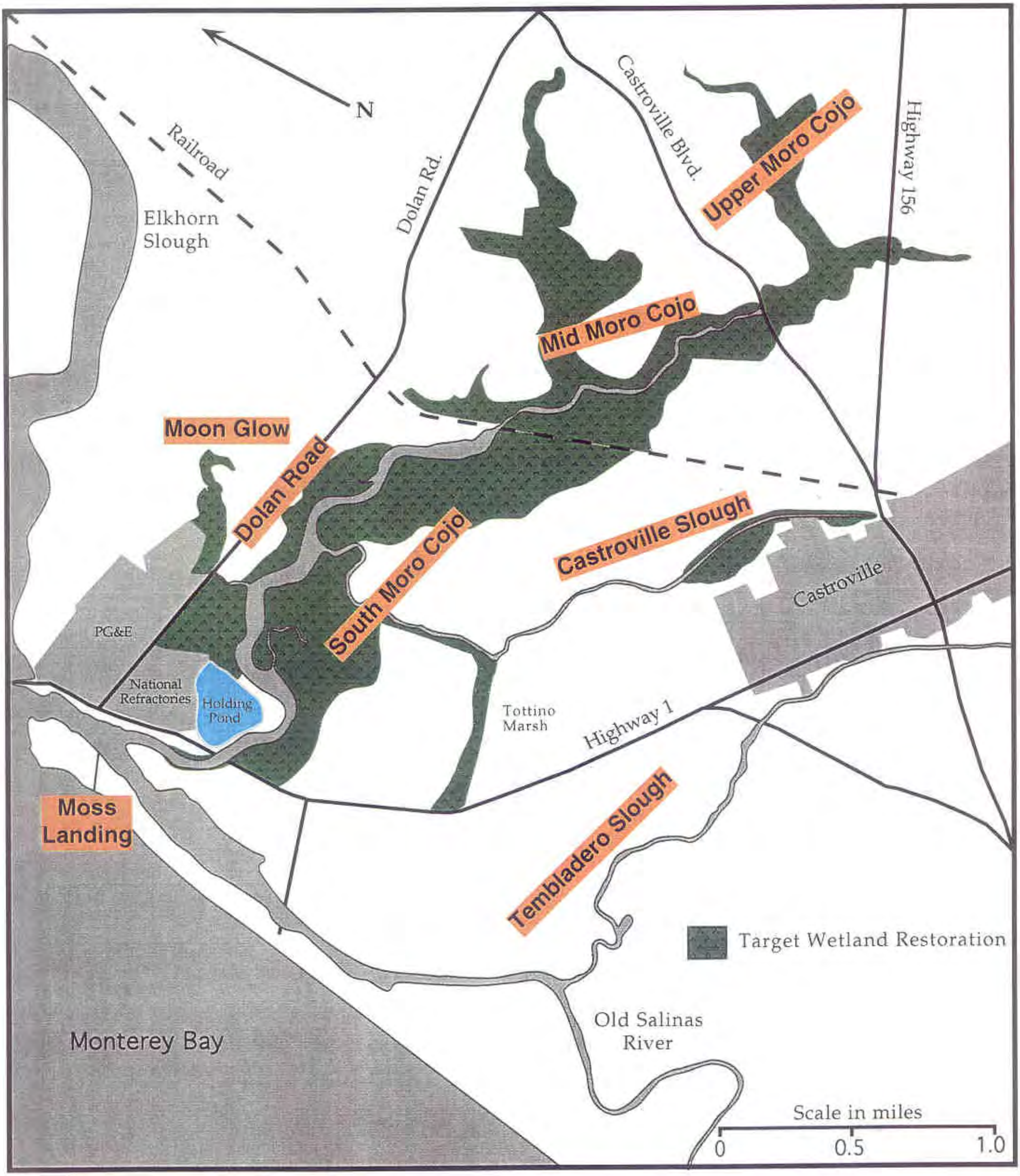


Figure 6: Target wetland restoration areas in Moro Cojo Slough.

might be used, where water management areas are exempt from normal regulatory policies such as those involving species of special concern and wetland delineation. However, the failures and successes from other regions should be thoroughly explored. Another idea is the "one-stop" permitting process where regulatory agencies agree on one lead agency for permit application or another type of streamlined permit process for restoration within a watershed boundary.

There are five major categories of land use which will likely require the development of different types of landowner incentives: public, farming, grazing, rural residential, wet grazing/farming, and mitigated developments. It is most difficult to gain landowner permission for farm land because it often has the highest economic return in its present use. Most grazing land is on steeper slopes above the valley floor and has much lower economic value making landowner participation easier to obtain. Wet grazing and farming land uses occur in most of the low areas of the Moro Cojo Slough, where there is essentially no farming and limited grazing because the land is often wet even where there are drainage channels. Landowner participation is easier to obtain here than in the higher value drier soils.

Although it is important to develop landowner incentives for wet corridor restoration on all types of land use, the Watershed Institute's implementation efforts are proceeding in this general order of land use: public lands, mitigated developments, wet grazing/farming, grazing, and farming. The greatest need now is to define the best landowner incentive for each of these different land use types and to develop demonstration projects to illustrate their successful application.

5.2 Land Form Changes

The first on-the-ground task is changing land forms usually to divert water into a more natural course, spreading it over low, broad areas and ponding it whenever possible. In the Salinas Valley, drainage ditches are the main land form that needs to be modified for restoration. Usually, the ditch should be filled at a location which spills water over the broadest low area. The Watershed Institute has used hay bales, sediment, larger rocks, and wetland plants to divert water from ditches into adjacent low areas or into a more meandering channel. Adjacent land can be protected from flooding with low-slope earth berms that are stabilized with appropriate native vegetation. Ditch edges can also be excavated and the sediment deposited along the sides of the widened ditch in the same low-slope berms with native plant cover. Since many low wet areas were filled during past land uses, another common land form change is to grade or excavate the fill using the excavate to protect adjacent areas from flooding. All these land form changes result in a significant increase in flood storage capacity.

Water drainage from farm and other lands surrounding the wet corridors must be drained into the wetland. The drainage includes water flowing on the surface of the field as well as water drained with tile drains and pipes below the soil surface. The subsurface drainage system will constrain wet corridor restoration in some lower flood plain areas.

Most grazing land in the Salinas Valley has also been drained by ditches. Here, in addition to channeling water out of the ditch and over low areas, grazing animals such as cattle must be excluded with fencing from wet corridor restoration sites. These corridors are generally only a small area of grazing ranches and access to water can be provided for livestock.

5.3 Non-native Plant Control

A long history of human activities in the region has introduced a wide variety of non-native plants that thrive in temperate climates, especially in landscapes disturbed by human activities (Gordon 1996). The need for non-native plant control varies considerably with different land use practices, with vegetation history, and with duration of standing water on a site. At existing Watershed Institute restoration sites, non-native plant control has been easier in wet areas compared to adjacent drier habitats. There are two common non-native plant categories in the wet corridors: large herbaceous plants and annual rye grass. Both groups can be reduced by mowing and by herbicides. The most common herbaceous species are poison hemlock, wild radish, mustard, and dock. Mowing is timed to minimize seed production in the non-native species which have the highest negative impact on colonization of native flora. Hemlock, when abundant, is always the first species to target. It forms a tall, dense monospecific stand and is an excellent colonizer of newly disturbed sites. Wild radish and mustard can form similarly dense, monospecific stands and are renowned invaders. Non-native plant control is rarely successful without replacing the non-native species with native species. Otherwise, the removal of one non-native plant is followed by the colonization of another. Since the seeds of many plants, including the non-natives, persist in soils for many years, some non-native plants must be controlled for many years. When non-native plant control activities are timed correctly, non-natives can be minimized usually within three years while encouraging native plant establishment.

5.4 Native Plant Establishment

The general strategy for establishing native plants is to mimic natural successions as much as possible. This can start during non-native plant control by spreading seeds of both early and late successional species, which will replace the non-native weeds. Seed germination is greatly enhanced by good seed to soil contact from walking, raking, or drilling. In addition to broadcasting or drilling seeds, restoration sites are planted with a mix of native trees which usually include species of willows, cottonwoods, sycamore, maple, elderberry and creekside dogwood. These are often irrigated by drip lines or water truck during the first year. The riparian trees can grow to a large size with full canopies within five years. These canopies restrict the survival and recruitment of the most invasive non-native plants, and are thus another weed control strategy. Other native species are planted from nursery stock whenever appropriate including sedges, rushes, and grasses such as creeping wild rye and salt grass which spread more rapidly from established root stock compared to seeds. In general, non-native plant control and native plant establishment occur together to shift the plant community from invasive non-native plants to early successional species in a natural local plant succession. Animals rapidly colonize restoration sites as the vegetation develops, and at present no planned animal introductions have been desirable.

6. Restoration Examples

6.1 Examples in Moro Cojo Slough

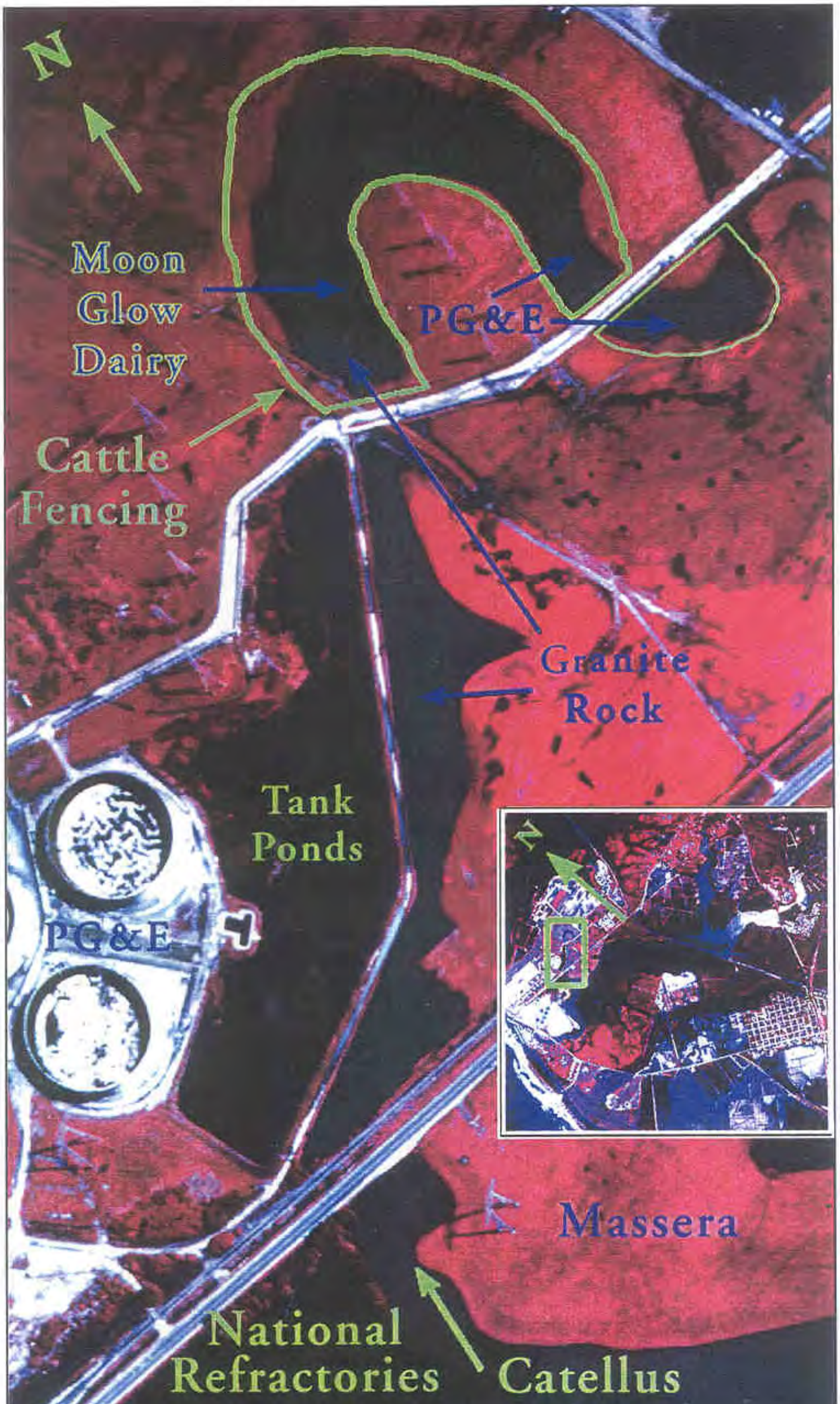
The Watershed Institute has initiated a number of wet corridor restoration projects throughout the Monterey Bay area (Figure 5), with a major demonstration area being the Moro Cojo Slough (Figure 6). Much of this work was supported under the companion 319(h) grant for implementing water management areas to filter non-point source pollution from valley drainage water. Despite the drainage system in Moro Cojo, this land is wet for almost half of the year and is therefore rarely used for farming. The entire area is designated as Resource Conservation land use in the Monterey County Local Coastal Program, but cattle are still grazed in large areas with highly significant negative impacts to native vegetation. The Moro Cojo watershed has seven restoration project areas (Figure 6) where simple changes in land form have had a profound impact on hydrology and water resources. The important restoration components for four of these geographic areas are considered below as examples of what can be done throughout the Salinas Valley.

Additional restoration activities are identified for the Moro Cojo in the Moro Cojo Slough Restoration Plan (1996), prepared by the Coastal Conservancy and Monterey County. Most future implementation of the restoration plan depends on the development of landowner incentives for participation (section 5.1). Representatives from the Technical Advisory Committee for the plan have been considering costs, funding sources, and time lines for the highest ranked sites. The present ranking is determined primarily by landowner interest in participating.

6.1.1 Moon Glow Marsh

Permission: Moon Glow Marsh crosses three legal parcels with different owners (Figure 7). Two owners gave permission to begin restoration to use the marsh, a

Figure 7. Cattle should be removed from the marsh in Moon Glow Dairy region. This site is crossed by the PG&E pipeline (above) and Dolan Road (below.)



water management area, to filter drainage water from Moon Glow Dairy. The last owner will require additional incentive.

Land Form & Hydrology: No land form changes are needed here. The simple hydrologic change is to place a riser on the Dolan Road culvert or to place a dam in front of the culvert to pond water over the entire marsh. The marsh is presently drained in a ditch to the culvert. The marsh must also be fenced to exclude cattle, which has already been done in the upper marsh nearest the Dairy (Figure 7).

Non-native Plants: Cattle have heavily grazed the area for many years and the most invasive non-native plants are not abundant. However, curly dock may become abundant and require removal.

Native Plants: Many wetland plants are still present and have extensive root systems- e.g., rushes, spike rushes, sedges, salt grass, pacific silverweed, and pickleweed. Once the cattle were removed from the upper marsh (Figure 7), there was a rapid recovery of these species, especially because the cattle were excluded during the wet season. Willows, cottonwoods and creekside dogwoods were planted this year from rooted stock, and some willows from cuttings.

6.1.2 Castroville Slough

Permission: Along the east side of Castroville, the slough crosses five parcels with different owners (Figures 8-10). Permission to restore habitat on three of these parcels has been obtained. Access to the other two parcels may be obtained in sustainable development plans for the upland portions of the parcels within Castroville's town limits.

Land Form & Hydrology: A flood control ditch drains the Castroville Slough. It can be blocked with ecological engineering to divert flow back over the historical marsh area (Figures 8 & 9). Here large ponds can be excavated for surface water retention to use for irrigation, fish farming, and wildlife habitat. When the marsh area fills with water, the overflow continues along the flood control channel (Figures 8 & 9). The upper slough is fed by a culvert under Highway 156. The flow from this culvert can be diverted away from the ditch and spread over the historical marsh area (Figure 10). Again, once this area is full of water, the overflow continues down the flood control channel.

Non-native Plants: Hemlock and wild radish removal is required at all sites before water is ponded. Ponded water should exclude these and most other weeds from the main marsh areas, with some removal required at the marsh edge.

Native Plants: Since the entire site has been plowed for farming, there are few native plants present. Native grass seeds and seeds of other natives should be spread over the entire area as weed control proceeds. Riparian trees and bushes can be planted around the marsh edges, and other rooted native plants can be introduced throughout the area.

6.1.3 South Moro Cojo Slough

Permission: The lower (Figure 11) and upper sections (Figure 12) of South Moro Cojo cross three major parcels with different owners. Permission to restore these sites is in negotiation and dependent on landowner incentives (Section 5.1).

Land Form & Hydrology: The lower and upper sections of South Moro Cojo are fed by different sources of water. The lower section receives water from the Castroville Slough (Figure 11). At present the water in Castroville Slough is pumped into a diked channel which flows into the main channel of Moro Cojo. This flow can be diverted outside the channel to flow behind the dike and fill the large historical marsh owned by Catellus Inc. (Figure 11). Since this area is surrounded by a dike, the entire site will pond water and overflow across the Elkhorn Slough Foundation's land adjacent to Highway One (Figure 11). Large deep ponds can be excavated to increase greatly the retention of surface water for irrigation and wildlife habitat. Excavated material can be used to broaden and stabilize existing dikes or to build up farm edges. Drainage water from adjacent farming operations can also be diverted into the PG&E parcel along a new riparian corridor (Figure 11), primarily for filtering water but also to enhance all water resources.

The upper section of South Moro Cojo is fed by water from the major watershed of the slough, which flows through an opening under the railway dike along the main slough channel (Figure 12). Water can be ponded from the railroad to Castroville Boulevard with a berm under the rail road (Figure 12). After the water flows over this berm, it can be deflected out of the main channel with a low ecologically engineered berm and into the diked historical marsh next to Sea Mist Farms (Figure 12). The flow can be directed in and then out of the diked area through low openings in the dike. Except during periods of extreme flooding (as shown in both Figures 11 & 12), the present flow is directed only through the main channel and into Moss Landing Harbor. The dikes along this channel prevent most flow from spreading into the large historical marsh areas flanking the channel.

Non-native Plants: There are no significant non-native plant problems in this area of the slough. It has been heavily grazed by cattle or periodically plowed for decades, and is also periodically covered with flood waters which limit the survival of many non-native plants.

Native Plants: Most of the area should be covered by low growing wetland grasses, sedges and rushes with larger trees along selected borders. Farm edges should be planted in native grasses or other low growing forms. If deeper ponds are excavated for surface retention and irrigation, these should be planted with species, such as creeping wild rye, which have low water requirements compared to species such as willows. Where the historical marsh has not been plowed, there will be considerable regrowth from native root systems.

6.1.4 Mid Moro Cojo Slough

Permission: There are three major landowners in the mid Moro Cojo area (Figure 13). Part of the marsh land around both the Dolan and Calcagno properties is already wet, and only requires limited enhancement with native plants. The main slough area is used only for cattle grazing and is designated as Resource Conservation land use in the Monterey County Local Coastal Program. This area will require landowner incentives for permission to restore (Section 5.1).

Land Form & Hydrology: A low berm at the opening under the railroad will pond water to Castroville Boulevard (Figure 13). If a higher water elevation is desirable (e.g., for greater surface water retention for irrigation), the elevation of Castroville Boulevard must be raised accordingly to prevent prolonged flooding over the road.

Non-native and Native Plants: Similar to South Moro Cojo.

6.2 Other Wet Corridor Restorations

There are two main types of wet corridors where the Watershed Institute has implemented restoration under the companion 319(h) project: riparian corridors and low marshes. Several examples are briefly described to illustrate the positive impacts on water resources. Once again, the costs, funding sources, and time lines varied tremendously among these additional examples of restoration projects. The examples involve public and private landowners who were involved in the founding and development of the Watershed Institute, and are therefore not normal examples of the prevailing challenges to gain land owner participation and permission to restore wet corridors.

6.2.1 Natividad Creek

This site is owned by the City of Salinas. A narrow drainage ditch was opened into a much broader stream channel during the fall of 1994 as part of the development of Natividad Creek Park (Figure 14). Hay bales were placed along the channel to capture sediment and water, which produced excellent seed beds for colonizing plants and water after the wet season (Figure 15). Since there was considerable excavation to create the wider channel, non-native plants were not abundant here, except for curly dock which flourished in the wettest areas and can be eliminated or greatly reduced in the future. There was nearly 100% cover of wetland plants during the second year of restoration (Figures 14-16). The site was extensively seeded and planted with native species and drip irrigated as part

Figure 8. A restorable section of Castroville Slough. The potential flow of diverted water after installation of a berm is shown.

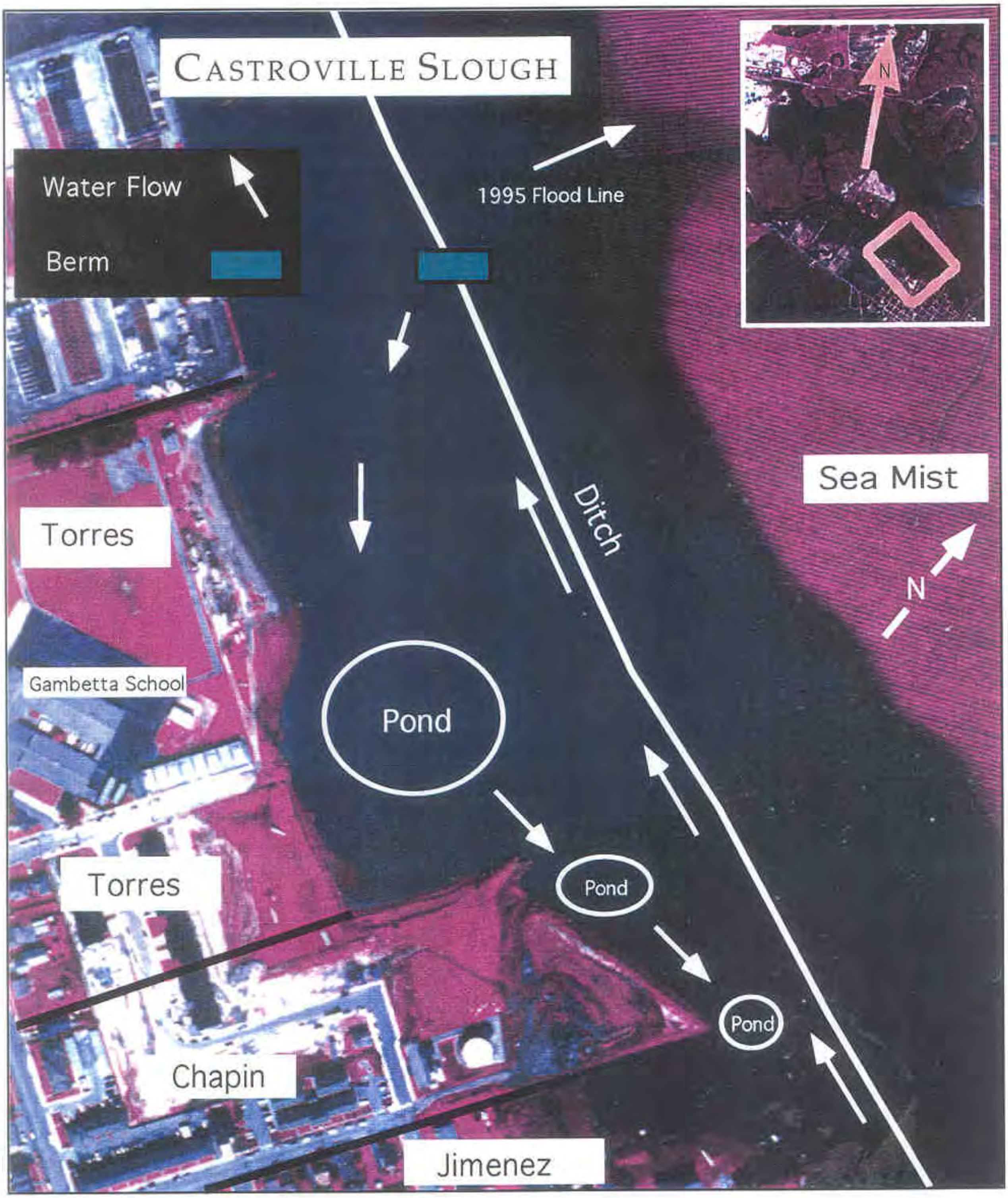
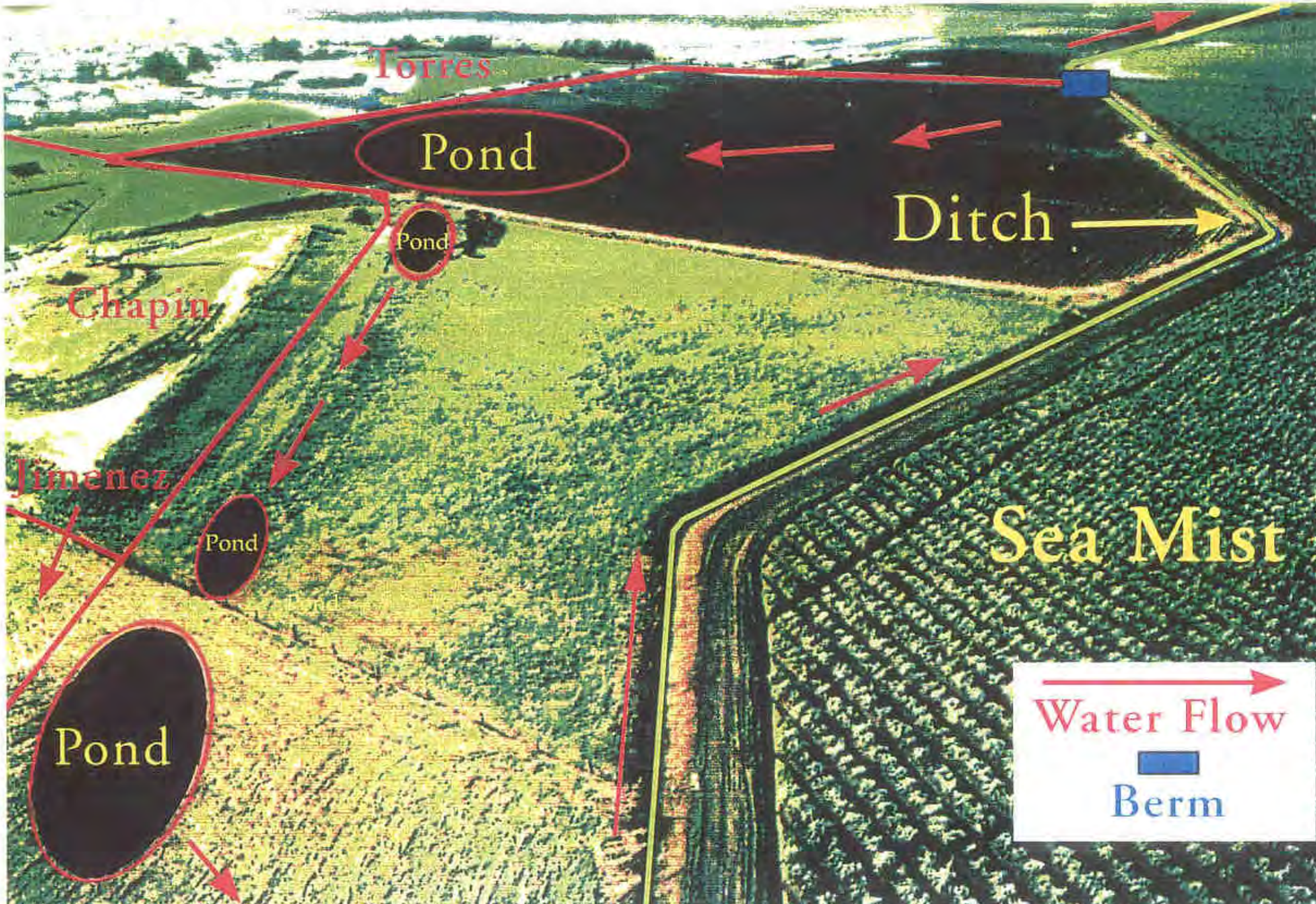


Figure 9. Looking northwest along the restoration area in the same region of Castroville Slough as shown in Figure 8.



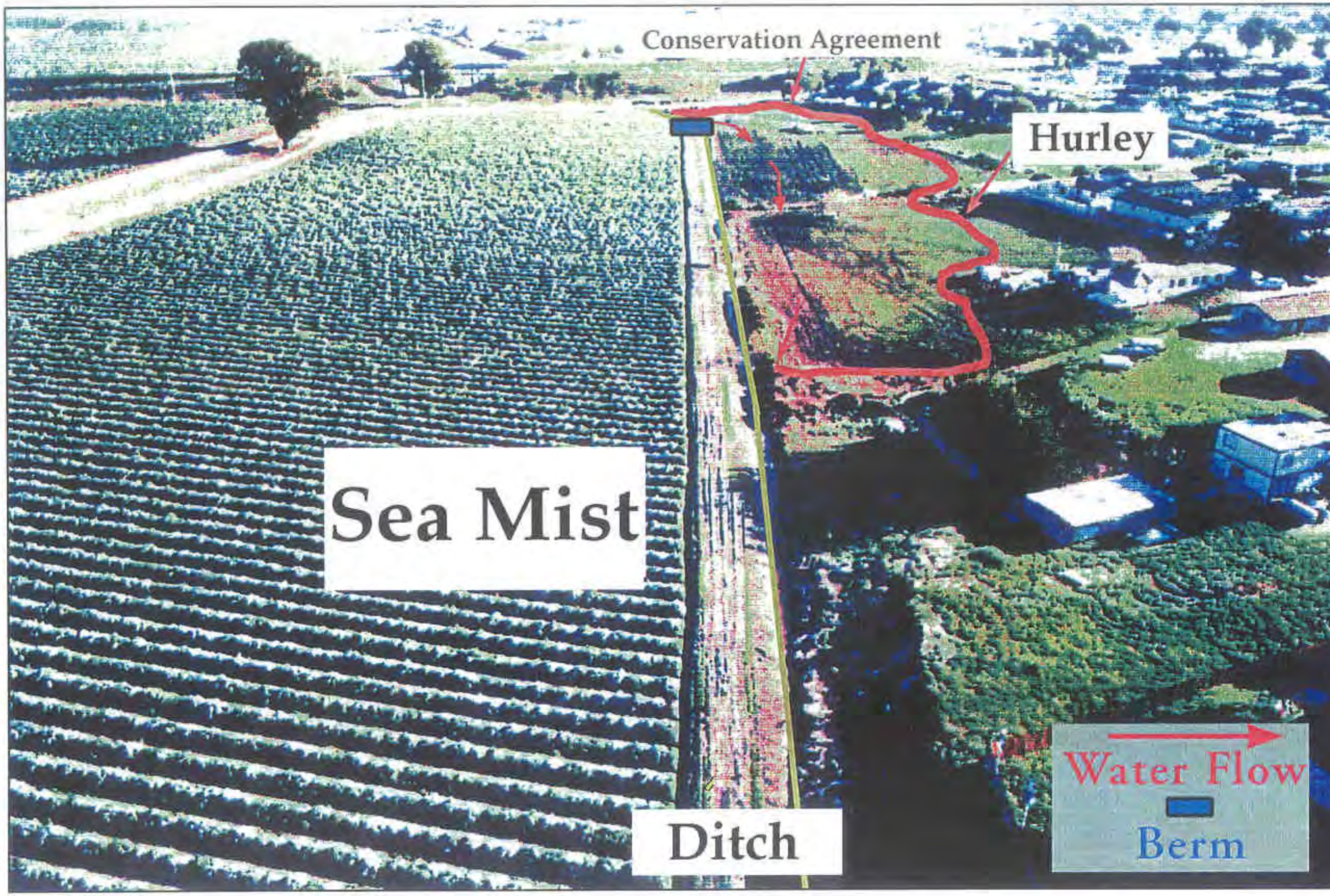


Figure 10. Castroville Slough looking south towards Salinas. Highway 156 is at the top.

Figure 11. South Moro Cojo Slough. There are large areas of restorable marsh possible with minor changes in water flow.

Figure 12. Additional restorable area in the South Moro Cojo Slough region (east of the area shown in Figure 11). The Southern Pacific Railroad cuts across the marsh.

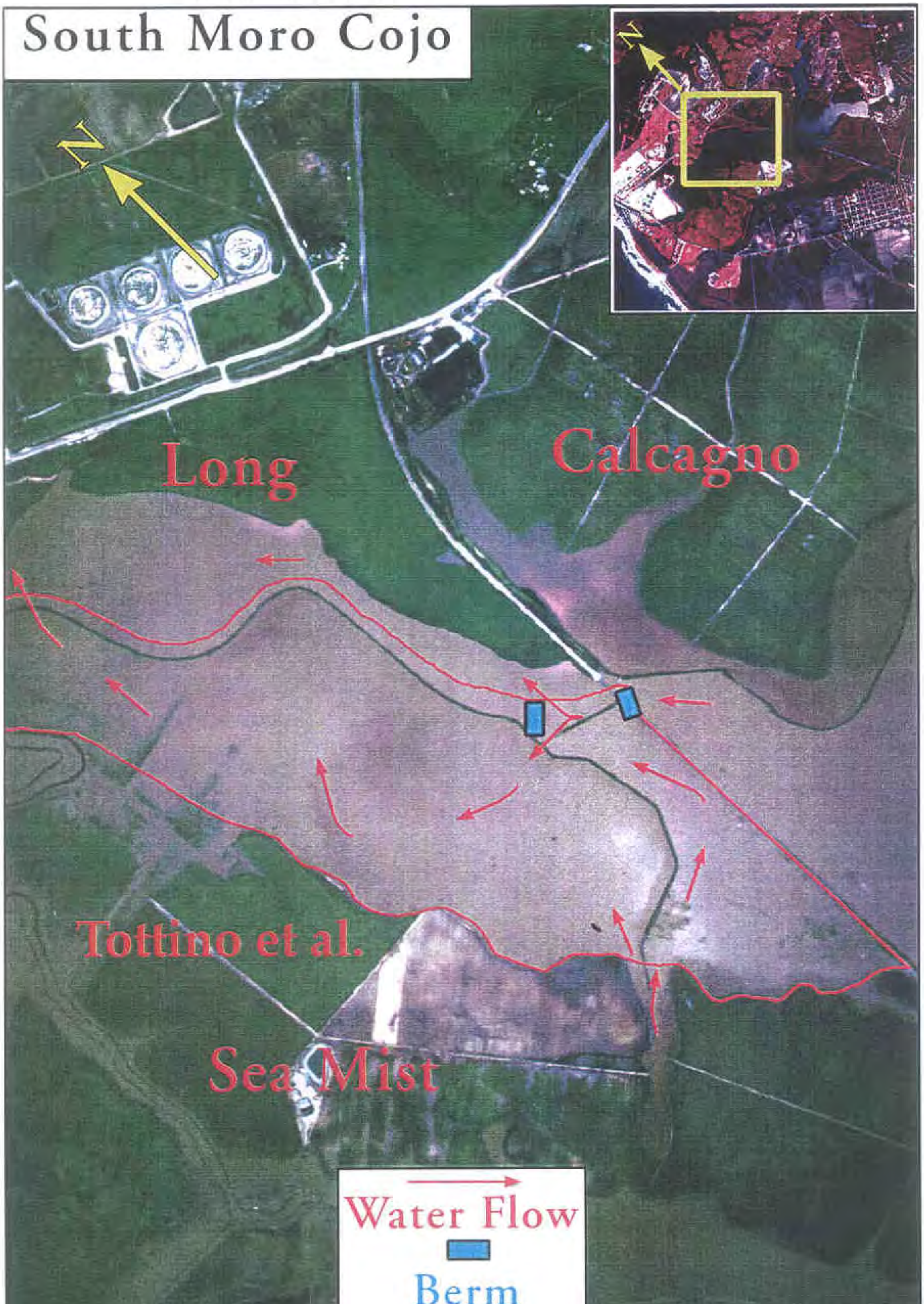


Figure 13. The Mid-Moro Cojo Slough is east of the railroad.

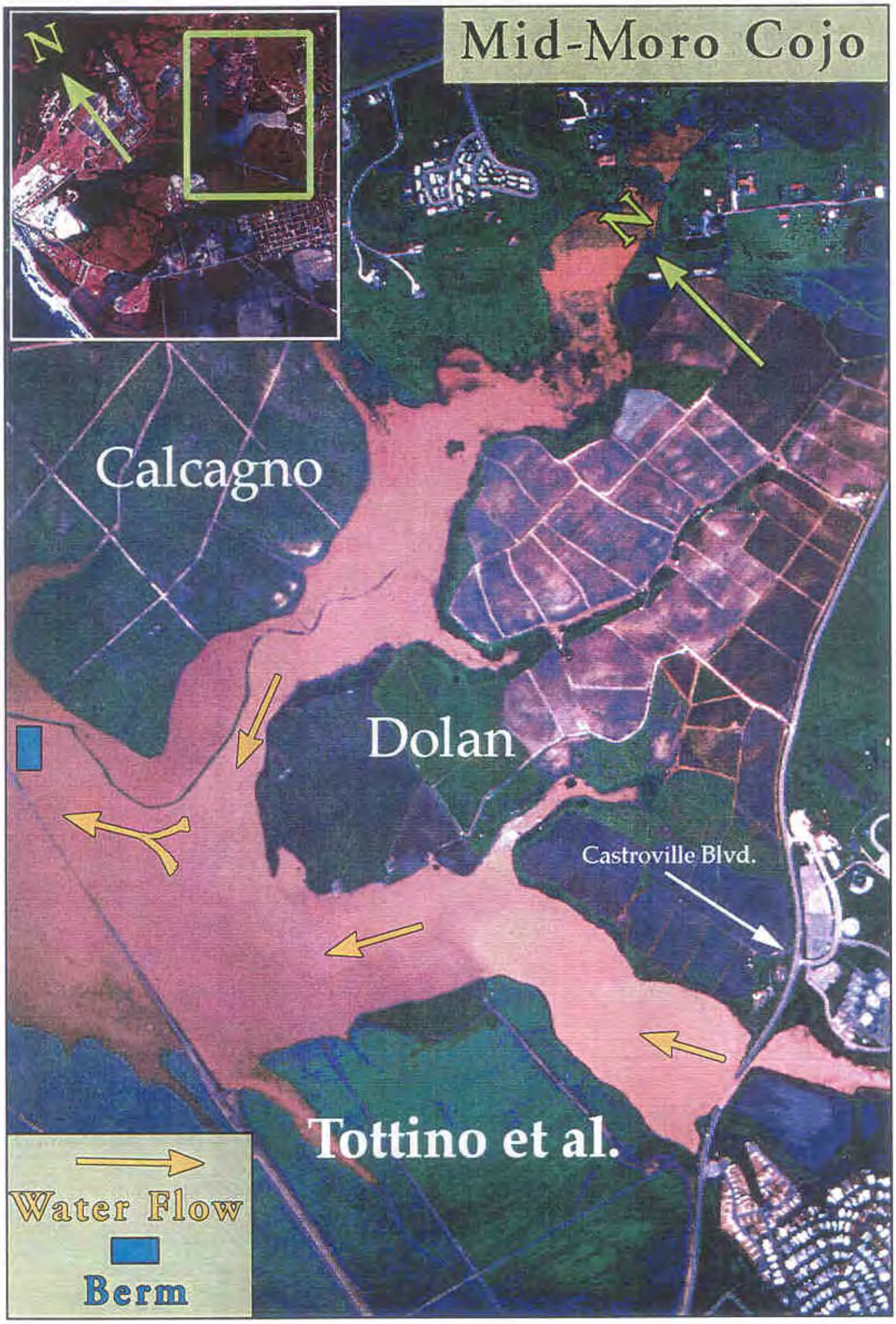


Figure 14. Natividad Creek during the first (1/95 at top) and second year (3/96 at bottom) of restoration.

Figure 15. Closer view of Natividad Creek during the first year (1/95) and the third year (6/97) of restoration.

Figure 16. Additional views of three year old habitats (6/97) along Natividad Creek.

Figure 17. Hansen Slough restoration in the first (1/94: top) and third year (3/96: bottom) looking north with Harkins Slough Road crossing the photo tops.

Figure 18. Closer view of three year old habitats at Hansen Slough.

Figure 19. Second year of restoration at Moon Glow Dairy showing the PG&E site where cattle were excluded and wetlands rapidly recovered.

of the Return of the Natives Project (see Section 10). Overall survivorship of plants was 90% using these methods.

6.2.2 Other Riparian Corridors

The steeper hillsides along both sides of the Salinas Valley are traversed by hundreds of seasonal streams and smaller drainages. Most are ditched and grazed by cattle. A number of these riparian corridors were fenced to exclude cattle and stuffed with hay bales to slow and pond water on the Porter Ranch in the Elkhorn Slough (Figure 21). Nearby, the Walker Creek riparian corridor represents many parcels in rural residential neighborhoods were water usually flows through unvegetated ditches. This site was colonized by two endangered species as soon as water was ponded (Figure 22 & 23).

6.2.3 Low Marshes

The best example of restoration in a low marsh area is Hansen Slough near Watsonville (Figure 17). This area was farmed during dry years until restoration began in the winter of 1994. A drainage ditch along the low side was converted to a meandering creek along the high side of the parcel, spreading water over the entire site (Figure 17). Hay bales directed the water and were covered with transported sediment and colonizing vegetation to form stable, new stream banks. Hemlock and other large non-native plants were greatly reduced by mowing in the first year, but non-native rye grass covered about 1/2 of the site. This was mowed through the second year and should be greatly reduced in the third year, when mowing and herbicide treatments will be compared for rye grass eradication. Many hundreds of willows were started with cuttings and other trees were planted from rooted stock and sometimes drip irrigated for only the first year (Figure 18). Dense wetland communities easily coexist with intensive farming, even on steep hillsides (Figure 19). Farm roads are established along the wetland edge and sometimes crossing through marshes with no significant negative impacts (Figure 20).

7. MONITORING RESTORATION PROGRESS

The long-term monitoring of non-point source pollution and the success of water management areas for enhancement of water quality should focus on project sites and also include a series of baseline sampling stations especially in the major sediment sinks in the watershed. The monitoring program should emphasize water quality, but also concern ecological communities and hydrology. The State Mussel Watch program has already determined sampling stations for baseline water quality monitoring as well the protocol for monitoring restoration sites.

The monitoring program will address several concerns about the use of water management areas for filtering potentially toxic substances from drainage water.

The ultimate fate of trapped pollutants varies greatly among chemical contaminants, but they can be monitoring in the step-protocol described below. If they accumulate in sediment (bulk chemical analysis) and/or are a threat to wildlife (tissue and bioassay monitoring), the central sink of the water management area can be excavated and the sediment hauled away. This is done now in many retention ponds for sediment erosion under the excellent programs initiated by the Natural Resources Conservation Service. We do not expect ecologically significant long-term deposition of pollutants in water management areas, but rather continual degradation and recycling of non-toxic components (Oakden and Oliver 1990). Agricultural chemicals that persist in the environment and in animal tissues have largely been restricted in use or banned (e.g., DDT, toxaphene, endosulfan). Impacts to plants and animals from the present farm chemicals are likely to be sudden, catastrophic events (Oakden and Oliver 1990), if they occur, which can be detected in the ecological monitoring described below. There is little evidence of significant movement of chemicals trapped in wetland sediment sinks into ground water (Hammer and Bastian 1989, National Research Council 1992, Mitsch and Gosselink 1993). Ground water sampling done by Monterey County Environmental Health has detected no significant pesticide contamination of ground water, although potential problem areas were targeted for sampling. Nevertheless, if pollutants become elevated in sediments trapped in water management areas, nearby ground water can be easily monitored for contaminants. Appendix 3 was compiled by Melanie Truan and addresses the major background literature on non-point source pollution and wetlands as it relates to the above questions.

7.1 Water Quality Monitoring

Water quality should be monitored in a step-protocol, proceeding to the next step if the data from the first measures indicate degraded water quality (i,e low compared to reference sites). Sediment and nitrate in water are used as a general indicator of drainage inputs, particularly from farm, dairy, and grazing land. These inputs are monitored at peak rainfall at input and output flows from the restored wet corridors, and in ponded areas at key seasons (Figure 24). If high nutrients and/or suspended sediments are present or other information suggests a significant water quality problem, then a stepwise monitoring is done for pesticides, herbicides, and other contaminants by first sampling the tissues of freshwater clams (in the same way mussels are sampled in marine and brackish habitats), then in sediments from depositional sinks, and then in the tissues of indicator native species. The final step in extreme problems involves a series of realistic bioassays to target the primary chemical species. As expected from many other studies (Hammer and Bastian 1989, Gearheart 1992, and Appendix 3), suspended sediments and nitrates are dramatically reduced by the wetland filter (Figure 24).

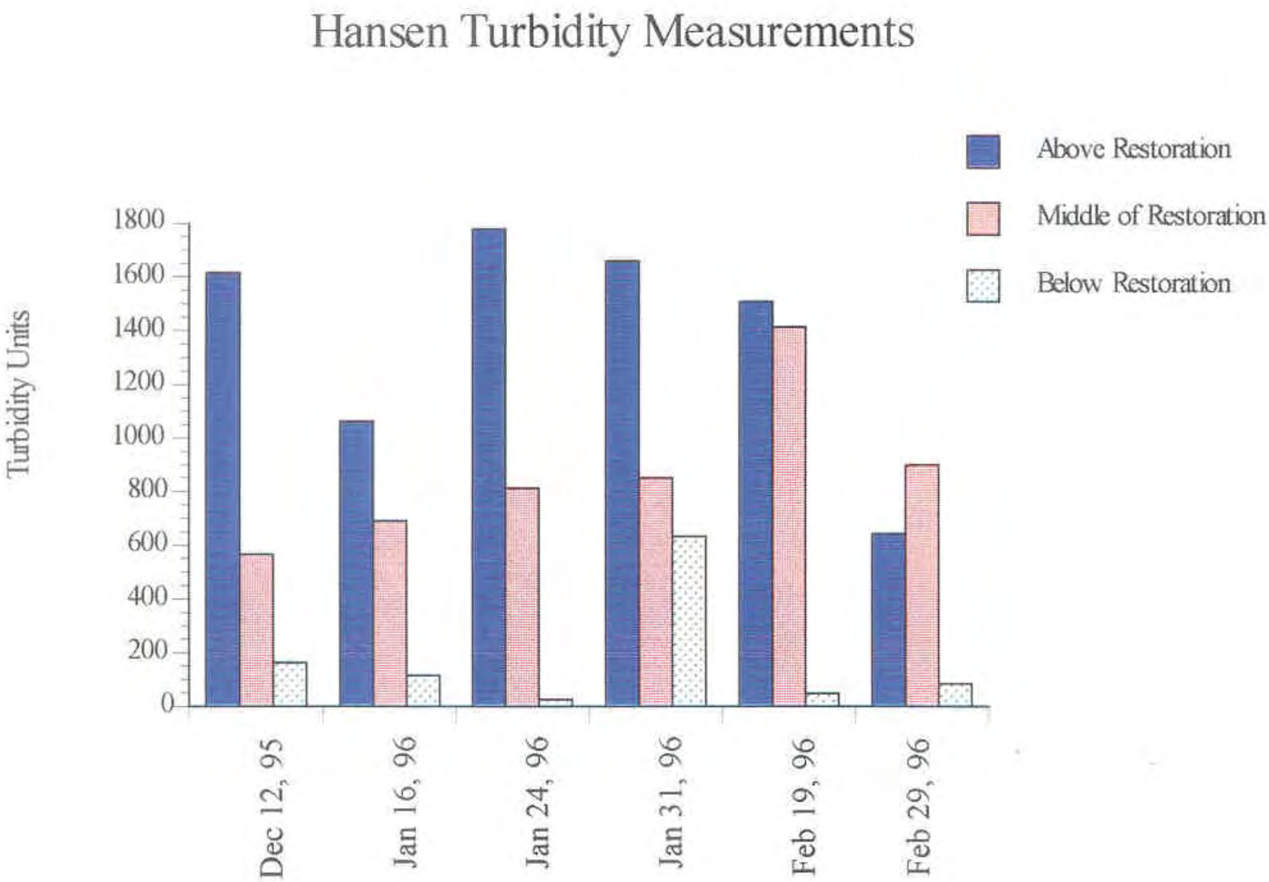
The State Mussel Watch program monitored the levels of pesticides and herbicides in the lower drainage ways of the Salinas Valley some years ago, and

Figure 20. Ten year old wetland in Moro Cojo Slough restored by blocking a drainage ditch (top) and a river dike vegetated with a native grass, creeping wild rye.

Figure 21. Healthy interface between native wet habitat and farming at Hansen Slough (top) and Moro Cojo Slough (bottom).

Figure 22. Restoration of riparian habitat along Walker Creek in a rural residential neighborhood: year one top (1/94), year four bottom (5/97).

Figure 23. Walker Creek in the first (top) and fourth year of restoration (bottom 5/97).



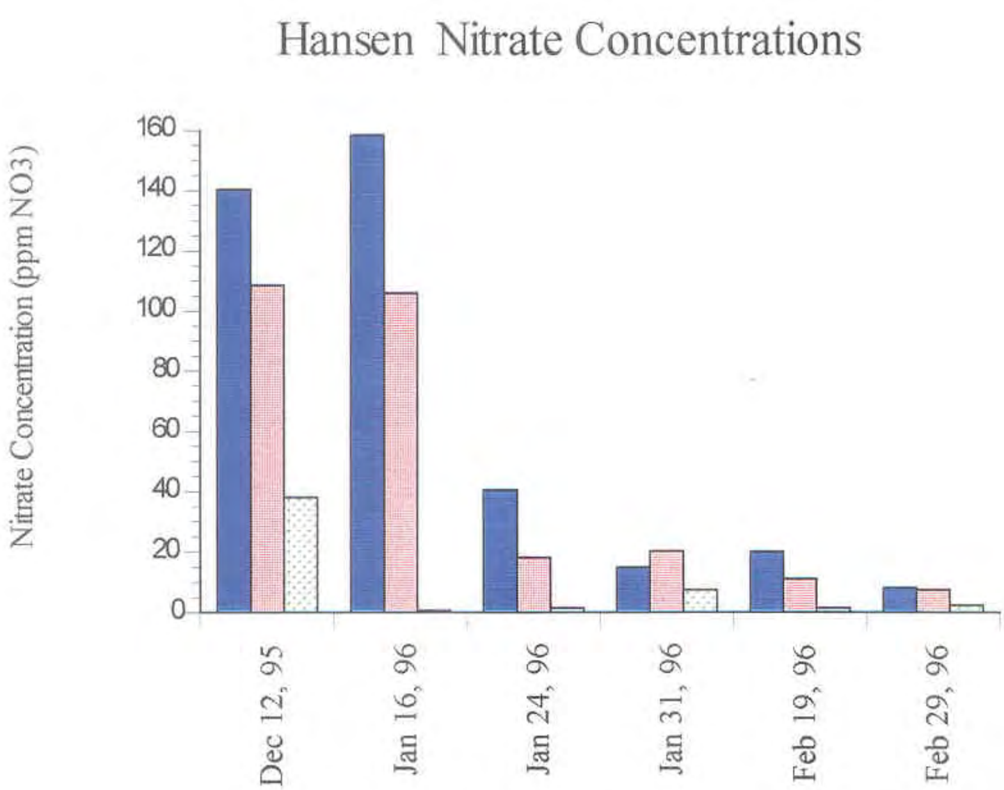


Figure 24. Turbidity and nitrate measurements at three sites through the drainage of Hansen Slough Restoration project during the winter rain events of 1995-1996.

Fig. 25a

Historic State Mussel Watch (SMW) Program and Toxic Substances Monitoring (TSM) Program Results That Exceeded NAS Recommended Guidelines*

Program	Station Number	Station Name	Sample Date	Total Chlordane	Total DDT	Dieldrin	Total Endosulfan	Endrin	Total PCB	Toxaphene	Chemical Group A**
TSM	309.10.04	Old Sal R/Mont Dunes BRG	08/24/83	•	•	•	•	•		•	•
TSM	309.10.05	Salinas R/Blanco Drain	08/24/83		•					•	•
SMW	405.40	Old Salinas River Ch. 1	11/28/83		•						
TSM	309.10.05	Salinas R/Blanco Drain	06/12/84							•	•
TSM	309.10.09	Blanco Drain/Salinas R	06/12/84							•	•
TSM	309.10.02	Lower Tembladero Sl	06/13/84							•	•
TSM	309.10.13	Salinas Rec Canal/Davis Rd	06/14/84		•	•				•	•
SMW	407.50	Blanco Pump East	02/19/85		•						
SMW	407.60	ML Drain Blanco D/S	02/19/85		•						
TSM	309.10.13	Salinas Rec Canal/Davis Rd	06/04/85	•	•	•				•	•
TSM	309.10.15	Blanco Drain/Hitchcock Rd	06/06/85		•	•	•			•	•
TSM	309.10.13	Salinas Rec Canal/Davis Rd	10/01/86	•	•	•	•			•	•
TSM	309.10.17	Salinas Rec Canal/Airport Rd	10/01/86		•	•	•			•	•
SMW	407.50	Blanco Pump East	12/11/86		•						
SMW	407.80	Blanco-Hitchcock	12/11/86		•						
SMW	408.90	Reclamation Canal #3	12/11/86		•				•		
SMW	409.00	Reclamation Canal #4	12/11/86		•						
TSM	309.10.13	Salinas Rec Canal/Davis Rd	08/11/87		•	•				•	•
TSM	309.10.17	Salinas Rec Canal/Airport Rd	08/13/87		•	•	•			•	•
SMW	409.0	Salinas/Rec. Canal 4	02/03/88		•						
TSM	309.10.10	Alisal Slough/West Salinas	07/25/88		•		•			•	•
TSM	309.10.06	Salinas Rec Cl/u/s Temb. Sl	07/26/88		•	•	•			•	•
TSM	309.10.91	Alisal Sl/u/s Tembladero Sl	07/27/88				•				•
TSM	309.10.09	Blanco Drain/Salinas R	09/04/91	•	•	•			•	•	•
TSM	309.10.05	Salinas R/Blanco Drain	08/11/92		•					•	•

u/s = upstream of

* The National Academy of Sciences (NAS) has established recommended maximum concentrations of toxic substance concentrations in fish tissue. They were established not only to protect the organisms containing the toxic compounds, but also to protect the species that consume these *contaminated organisms*. The State Mussel Watch Program only applies these guidelines to Total DDT and Total PCB, while the Toxic Substances Monitoring Program applies the guidelines to the following chemicals: Mercury, Total DDT, Total PCB, aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, Total chlordane, lindane, Total hexachlorocyclohexane, endosulfan, and toxaphene.

** Chemical Group A includes aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, Total chlordane, Total hexachlorocyclohexane, Total endosulfan, and toxaphene. The NAS recognizes the potential threat to *predator species of a combination of pesticides* and has developed a guideline for the combined or singular concentration of these pesticides.

*Historic State Mussel Watch Program Results That Exceeded Maximum Tissue Residue Levels**

Station Number	Station Name	Sample Date	Aldrin	Cadmium	Total Chlordane	Total DDT	Dieldrin	Heptachlor-epoxide	Total PCB	Total PAH	Toxaphene
404.0	Sandholt Bridge	11/05/87			•	•	•		•		
403.6	Moro Cojo Slough	02/02/88			•	•	•		•		
404.0	Sandholt Bridge	02/02/88			•	•	•		•		
408.9	Salinas/Rec. Canal 3	02/03/88			•	•	•	•	•		•
409.0	Salinas/Rec. Canal 4	02/03/88	•		•	•	•		•		•
404.0	Sandholt Bridge	04/07/88			•	•	•		•		
404.0	Sandholt Bridge	12/08/88			•	•	•		•		
403.2	Moro Cojo	01/04/89			•	•	•	•	•		
404.0	Sandholt Bridge	01/04/89			•	•	•		•		•
404.0	Sandholt Bridge	02/19/90			•	•	•		•		
404.0	Sandholt Bridge	02/04/91			•	•	•		•	•	
404.0	Sandholt Bridge	01/28/92			•	•	•		•	•	•
405.2	Old Salinas River 2	03/16/92		•							
405.3	Old Salinas River 1	03/16/92		•		•	•		•		•
404.0	Sandholt Bridge	02/01/93			•	•	•		•	•	•
405.2	Old Salinas River 2	03/10/93			•		•		•		•
405.3	Old Salinas River 1	03/10/93	•	•		•	•	•	•		•
406.5	Tembladero Slough	03/10/93	•		•	•	•	•	•		•
407.4	Blanco Pump/West	03/10/93	•		•	•	•		•		•

* MTRLs were developed by SWRCB staff from human health water quality objectives in the *1990 California Ocean Plan*, the *Draft November 26, 1990 Functional Equivalent Document-Development of Water Quality Plans For: Inland Surface Waters of California and Enclosed Bays and Estuaries of California*, and the *Draft April 9, 1991 Supplement to the Functional Equivalent Document*. The objectives represent concentrations in water that protect against consumption of fish, shellfish, and water (freshwater only) that contain substances at levels which could result in significant human health problems. MTRLs are used as alert levels or guidelines indicating water bodies with potential human health concerns and are an assessment tool and not compliance or enforcement criteria. Tables 2, 3, and 4 in Appendix 4 lists MTRLs for those substances monitored in the State Mussel Watch Program.

Fig. 25b

Chemical Overview

Aldrin

Aldrin was developed for the control of soil insects. The EPA suspended nearly all uses of aldrin in 1974, with the exception of subterranean treatment of termites, moth proofing in manufacturing processes, and dipping of roots and tops of non-food plants. Subsequently, all uses on food crops were banned in 1985. It is a known carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act. Aldrin was primarily used over the years for structural pest control (yearly average 95%) and residential pest control.

Cadmium

Cadmium may be elevated in surface water due to fallout from air pollution, industrial discharge, or municipal effluent. Cadmium is used in electroplating, as a pigment in paints, and as a stabilizer in plastics. The bioavailability, toxicity, and potential bioconcentration of cadmium depends on the chemical form of cadmium. The free divalent cadmium is the most readily assimilated form. In aquatic habitats, particulate matter, dissolved organic material, and inorganic ligands will affect cadmium speciation. In addition, there is substantial variability in the sensitivity of fish species to cadmium. There is some evidence that trout and striped bass are more sensitive than other freshwater species. Cadmium is a known human carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Chlordane

Chlordane is a mixture of chlorinated hydrocarbons used alone or in combination with heptachlor for subterranean termite control. After April 1988, all use of existing stocks of these chemicals was prohibited. Chlordane is a known carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act. The primary purpose for application of chlordane in California was for structural pest control. Other uses for chlordane included residential pest control, landscape maintenance, and a small percentage for agricultural crops.

DDT

DDT and its congeners have been banned in the U.S. since the early 1970s because of their environmental persistence, adverse effect on wildlife, and potential carcinogenicity. While DDT levels have declined nationwide since use was discontinued, there is evidence that DDE levels in the biota have stabilized. The long half-life of DDE in biological tissue partially explains this trend. In addition, dicofol, a miticide used primarily on cotton in California, contains impurities of DDT-related compounds. The contribution of dicofol to tissue residues of DDE has been a concern. The EPA required the reduction of DDT and related impurities in dicofol to less than 0.1% by 1989. Nationwide, DDE residues in freshwater fish are about 400 ppb. DDT is listed by the State as a known carcinogen pursuant to the 1986 Safe Drinking Water and Enforcement Act.

Dieldrin

Dieldrin, an organochlorine pesticide, was used for the control of soil insects, public health insects, and termites. Dieldrin, the epoxide of aldrin, is bioavailable via the breakdown of aldrin in the environment or via direct application. In 1974, EPA suspended nearly all uses of dieldrin because of neurotoxicity and liver carcinogenicity to mammals. Subsequently, the use of dieldrin in California was cancelled. Dieldrin is a known carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Endosulfan

Endosulfan is a broad-spectrum insecticidal chlorohydrocarbon applied primarily to grapes, artichokes, alfalfa, tomatoes, melons, and head lettuce in California. Endosulfan is extremely toxic to aquatic organisms, adversely affecting growth and development in the parts-per-trillion range. Endosulfan is also acutely toxic to mammals. Endosulfan sulfate, the persistent breakdown product, is more toxic than the parent compound.

Endrin

Endrin is an insecticidal chlorohydrocarbon used alone or in combination with other insecticides for the control of insects on cotton and grains. It has also been applied to non-croplands for grasshopper control and to orchards for rodent removal. Endrin use has been sharply curtailed in the U.S. Only one product, a bird repellent, is registered with EPA and California. The mammalian toxicity of endrin is the highest of the cyclodiene insecticides such as aldrin, dieldrin, endosulfan, heptachlor, and chlordane. Despite endrin's high toxicity, the parent compound is metabolized and excreted more readily than other organochlorine insecticides. Toxic metabolites such as 12-ketoendrin may persist, however.

Heptachlor and Heptachlor Epoxide

Heptachlor, a chlorinated cyclodiene insecticide, was used to control soil insects on food crops until the mid-1970s. Subsequent use was then reduced and limited to structural pest control. Heptachlor is a known carcinogen, causing liver tumors in test organisms and, along with heptachlor epoxide, is listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act. The potential health risk from exposure to this termiticide by application to structures was one of the primary regulatory concerns of EPA. Heptachlor is acutely toxic to aquatic organisms, persistent in the environment, and bioaccumulates. Heptachlor's carcinogenicity, potential for bioaccumulation, and persistence led to its cancellation by the EPA. All uses of current stocks were prohibited after April 15, 1988.

PCBs

The EPA banned PCBs as a pesticide ingredient and cancelled registration of products containing PCBs in 1970. In 1977, the EPA promulgated zero discharge as the toxic pollutant effluent standard for PCB capacitor and transformer manufacturers. PCBs are known carcinogens pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

PAHs

PAHs are a diverse group of compounds consisting of substituted and unsubstituted polycyclic and heterocyclic aromatic rings.

Toxaphene

Toxaphene, a mixture of 177 different chlorinated camphenes, is a broad-spectrum insecticide. Toxaphene has been widely used in California in the past, particularly on cotton. Other crops to which it was applied were alfalfa, broccoli, tomatoes, celery, beans, cloves, lettuce, cauliflower, and pears. Because of its extreme chronic toxicity to aquatic organisms, toxaphene has been used as a pesticide to remove non-game fish. However, toxaphene is a known mammalian carcinogen and has been placed on the State's list pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act. Because of toxaphene's high aquatic toxicity, mammalian carcinogenicity, and environmental persistence, it is no longer registered in California.

Chemical Group A

The exposure of aquatic organisms to a combination of environmental pollutants may be deleterious at levels below accepted standards for specific pollutants. The NAS recognizes the potential threat to predator species of a combination of pesticides and has developed a guideline of 100 ppb for the combined or singular concentration of certain pesticides. Included in this group of pesticides, termed Chemical Group A, are aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlorepoxide, HCH (including lindane), endosulfan, and toxaphene.

Source: Toxic Substances Monitoring Program, Ten Year Summary Report 1978-1987 identified several of the drainages to be among the most polluted in the state (Ladd et al. 1984, Watkins et al. 1984, Stephenson et al. 1979, 1980: also see the Harbor Appendix 1). It is important to repeat this baseline sampling at least every five years using the same protocol outlined above at most of the past stations occupied by Mussel Watch and at a few additional sites. These baseline data provide an essential background for evaluating the impacts of the water management areas. In addition to significant water quality improvements around the water management areas, there should also be a gradual improvement of water quality throughout the watershed. All water quality stations are located with GPS (global positioning system), and data are being stored in a GIS (geographic information system) format database. See Appendix 5 for the QA/QC plan for water quality monitoring and Appendix 4 for a more detailed description of the water quality monitoring program.

Historic water quality data from the lower Salinas Valley watershed collected by the State Mussel Watch and Toxic Substances Monitoring programs have been tabulated in Appendix 1 and compared with NAS and Maximum Tissue Residue Level recommended guidelines. Sites which exceeded these guidelines for trace organic compounds are listed in Figure 25 a-b.

Total DDT continues to be a primary pollutant of concern within the valley watershed, persisting within the environment since it was banned from use in the United States in the early 1970s. In addition to wide spread DDT contamination throughout the 1980s and early 1990s, total chlordane, dieldrin, and endosulfan also have been identified as agriculture based pesticides of concern within our watershed. The primarily industry based pollutants, Total PCBs, also have been identified by the State Mussel Watch Program to exceed the maximum tissue residue levels throughout the watershed. Most of these contaminants are either strictly regulated or banned from use within California and therefore demonstrate a long term pollutant load in the Salinas Valley.

More recently developed pesticides are not yet measured as standard practice in monitoring programs due to the expense and difficulty of analysis. While these chemicals have been developed to break down more rapidly than historic pesticides, they often require natural wetland features including oxic and anoxic conditions and exposure to sunlight to initiate chemical degradation. Future monitoring programs must identify the presence or absence of these currently applied chemicals within the watershed.

7.2 Ecological Monitoring

Ecological monitoring should focus primarily on plants as the best indicators of habitat development. Tree sizes are measured at the base of the trunk, at the widest part of the canopy, and at the tallest point. Trees are measured once a year near the end of the growing season and is relocated with GPS. This permits estimates of the survival, growth, and cover of the major trees as indicators of general plant growth. The cover of all major plant groups are measured from aerial or balloon photographs taken during peak green biomass at the end of spring each year. At the same time, more detailed measurements of plant cover and number are collected along line transects in major habitat types and the entire area is surveyed for the total number of plant species. Ground photographs are also taken from permanent stations (GPS located) to document patterns of plant cover and species composition in key subhabitats.

At selected sites, birds and amphibians are surveyed at least once each year during periods of peak abundance. If episodic events occur such as pesticide spills, significant mortality can be detected by frequent qualitative surveys of water management areas. Qualitative surveys are often simply a field trip to each site by experienced naturalists who make direct observations of the major subhabitats and indicator species. All ecological monitoring stations are located with GPS and data are being stored in a GIS.

7.3 Hydrologic Monitoring

Eventually the flow rates of water in and out of the water management areas should be measured as well as the elevation and volume of water retained in each system. At selected sites, the elevation of ground water and movement of surface water into the local groundwater should be measured. The flood storage capacity of fully vegetated systems can be estimated and verified with field measurements.

8. WATERSHED EDUCATION

Public education is an essential component of successful watershed restoration, including programs in elementary, middle and high school. The Return of the Natives Project (RON) is the environmental outreach center from the Watershed Institute at CSUMB. RON involves communities and schools in the restoration of local creeks and wetlands while enhancing science and environmental education in area schools. RON develops native plant gardens and nature areas on school grounds as a vehicle for teaching science and environmental concepts. Students propagate native plants and take field trips to assist in habitat restoration. Over 25 Salinas schools are currently participating in the project. Lead teachers have been through intensive training workshops dealing with native plant ecology, habitat restoration, landscape architecture and curriculum development. Students learn relevant scientific concepts and processes by propagating and studying native plants, and being involved first-hand in restoration efforts. With Hispanics comprising over 50% of the Salinas student population, this project is an important opportunity to increase minority involvement in science. RON presently exposes hundreds of young students and families to the need and action of watershed restoration.

RON is also involved with college and community education about watershed restoration through both class curriculum and the service learning courses at CSUMB. The Earth Systems Science and Policy Institute offers formal courses in watershed science that are directly linked to hands-on involvement in solving community problems. This is service learning. Therefore, RON includes a public education pipeline from kindergarten to college and through the community.

In the past year, RON has been active in more schools and at more sites, and has involved more teachers and students, described in Appendix 7. Highlights include: last winter, about 1,730 students and 240 community volunteers planted over 20,000 plants at Natividad Creek Park in Salinas; 80 high school students participated in a 2 day restoration symposium; RON sponsored 10 CSUMB service learning students to serve as mentors in Salinas schools; a teacher training workshop was held; a Children's Discovery Garden was designed and built at Natividad Creek park; and a greenhouse was built and a restoration program initiated at North Monterey County High School next to Moro Cojo Slough. There are now over 20 greenhouse constructed by RON at various schools in the Salinas Valley.

Although RON activities focus on schools, they also involve communities around restoration sites from housing complexes to farm lands. The exchange of information with impacted communities is essential and one of the major roles of developing demonstration projects throughout the watershed to show other landowners and potential supporters. There are many other public and private organizations involved in public education about watershed restoration such as the Watershed Council, the National Marine Sanctuary, the Monterey Bay Aquarium, and the National Estuarine Research Reserve.

9. IMPLEMENTATION

This plan is being implemented by the Watershed Institute and their restoration partners in the demonstration projects from Moro Cojo Slough and throughout the Monterey Bay area that were highlighted in the plan. With the exception of the restoration of some erosion scars, wet corridor restoration requires at least five years to complete, although sites continue to change and sometimes need weeding or other restoration activities for much longer. Clearly past human history indicates that continuing, wise stewardship is essential for the restored sites to survive and function as water management areas. Since none of the demonstration projects is finished, complete cost estimates are unavailable. But the field restoration costs are a small sum compared to the likely public and private investment to gain permission to restore the wet corridors of the Salinas Valley (Figure 4).

Although this watershed restoration plan is developed for the northern Salinas Valley, it applies in large part to the entire valley and the Monterey Bay area. The major implementation tasks for the northern Salinas Valley are listed in the next section in their general order of importance.

9.1 Major Implementation Tasks

1. Develop landowner incentives for gaining permission to restore wet corridors on private lands and test these in demonstration projects throughout the Salinas Valley and Monterey Bay area; and develop costs for each type of landowner incentive as it applies to particular demonstration projects. Sustainable Conservation, the Natural Resources Conservation Service and AMBAG are likely lead organizations. This task is presently supported by the Packard Foundation. It will require additional support from the Monterey County Water Resources Agency, the Regional and State Water Resources Control Boards, the State Coastal Conservancy, and the Environmental Protection Agency.

2. Continue wet corridor restoration on existing and new sites where land owner permission has or will be obtained, especially the primary demonstration projects of this plan along the Natividad/Gabilan Creek watershed and Moro Cojo Slough (see section 6.1). The Watershed Institute is one lead organization for this task with support from the 319(h) grants and the Highway Enhancement and Mitigation Program. Future support will depend on partnerships with Monterey County Water Resources Agency, the State Coastal Conservancy, the Regional and State Water Resources Control Boards, the Natural Resources Conservation Service, and the Environmental Protection Agency.

3. Focus additional new permission programs and wet corridor restoration in the valley hills such as the Chular Hills for maximum impact on ground water recharge. The Natural Resources Conservation Service, Monterey County Water Resources Agency, and AMBAG are potential lead agencies for this task with target support from the 319(h) grant program, the Monterey County Water Resources Agency, and private sources.

4. Focus additional new permission programs and wet corridor restoration along the Salinas River, especially but not exclusively in the northern portion of the valley. Use the Salinas River Wildlife Area as a positive restoration model for the rest of the river system. Monterey County Water Resources Agency and AMBAG are potential lead agencies for this task with target support from the Highway Enhancement and Mitigation Program, Monterey County Water Resources Agency, the 319(h) grant program, and private sources.

5. Provide the baseline water quality sampling for the northern Salinas Valley using the protocols developed by the Mussel Watch program. Lead agencies for this task can be the National Marine Sanctuary and the Department of Fish and Game, with target funding from the Environmental Protection Agency,

Restoration cost estimate for the Salinas River Wildlife Area.

First Year		Cost Per Acre	Restore Acres	Restore Cost
Native Trees & Bushes	400/acre @ $3/tree	1200	25	30,000
Drip Irrigation Supplies	$500/ acre	500	25	12,500
Tree/ Drip Installation	70 hr/acre @ $12/hr	840	25	21,000
Tractor Mowing	2 hr/acre @ $60/hr- 3 x's	360	35	12,600
Weed wacking	10 hr/acre @ $12/hr- 3 x's	360	5	1,800
Seed Drilling	$200/ acre	200	40	8,000
Grass Seed	15 lbs/acre @ $20/lb	300	40	12,000
Seed Collect/Broadcast	3 hr/acre @ $12/hr	36	40	1,440
Irrigation Crew	6 hr/acre @ $12/hr- 6 x's	430	25	10,750
Misc. Maintenance Labor	2 hr/month @ $12/hr	290	40	11,600
Tool Maint/Replace	$75/acre	75	40	3,000
Field Coordination	20 hr/year @ $20/hr	400	40	16,000
Project Administration	@ 10%			14,000
		1st Year Cost		**154,690**

Second Year				
Tractor Mowing	2 hr/acre @ $60/hr- 3 x's	360	35	12,600
Weed wacking	10 hr/acre @ $12/hr- 3 x's	360	5	1,800
Seed Collect/Broadcast	3 hr/acre @ $12/hr	36	40	1,440
Misc. Maintenance Labor	2 hr/month @ $12/hr	290	40	11,600
Tool Maint/Replace	$25/acre	25	40	1,000
Field Coordination	5 hr/year @ $20/hr	100	40	4,000
Project Administration	@ 10%			3,200
		2nd Year Cost		**35,640**

Third Year				
Tractor Mowing	2 hr/acre @ $60/hr- 3 x's	360	20	7,200
Weed wacking	10 hr/acre @ $12/hr- 3 x's	360	1	360
Seed Collect/Broadcast	3 hr/acre @ $12/hr	36	40	1,440
Misc. Maintenance Labor	2 hr/month @ $12/hr	290	40	11,600
Tool Maint/Replace	$25/acre	25	40	1,000
Field Coordination	5 hr/year @ $20/hr	100	40	4,000
Project Administration	@ 10%			2,500
		3rd Year Cost		**28,100**
		Total Cost		**218,430**

Note: no planning or monitoring included.

the National Marine Sanctuary program, and Monterey County Health Department.

6. Expand the RON program throughout the Monterey Bay area, especially next to demonstration restoration regions such as the Moro Cojo Slough (North County High School and Castroville schools) and the Carmel River (Carmel High School, etc.). The lead agency for this task is the Watershed Institute with support from the City of Salinas, CSUMB, and private foundations.

7. Develop a range of cost estimates for landowner incentives and field restoration tasks on a per acre basis, based on the ongoing demonstration projects. AMBAG, Sustainable Conservation, and the Watershed Institute are potential lead agencies with target support from Monterey County Water Resources Agency, the State Coastal Conservancy, CSUMB and the Regional and State Water Resources Control Boards.

9.2 Moro Cojo Watershed Implementation

The Moro Cojo Wetland Management Plan recommends a number of specific implementation tasks for the area. This section outlines the status of the primary task of gaining permission to restore wet areas on private land. Slough parcels can be divided into three major groups because of the difficulty in gaining permission and the need to develop landowner incentives for restoration. The first category is existing projects. These are ongoing restoration projects that were largely initiated in the present planning process and the companion 319(h) project. These sites are in various stages of restoration, but land owner permission has been gained for all. They are spread throughout the watershed from the low marshes of the main slough into the Prunedale area (Figures 5 and 6). The geographic spread of these sites illustrates the difficulty of obtaining adjacent sites and the need to work on a parcel-by-parcel basis. Restoration funding has been from the 319(h) grant and other restoration grants at the Watershed Institute.

The second land category includes sites where there is the greatest potential for land owner participation based on past efforts to gain permission for restoration. These sites may not require new incentive programs. The third category includes the most important remaining parcels to restore all of the Moro Cojo Slough, the low area shown in Figure 6. This group is likely to require new landowner incentive programs.

The final category contains all of the remaining restorable parcels along the main section of Moro Cojo Slough (Figure 6). There are also many riparian corridors in the Prunedale area including the watersheds of Elkhorn Slough and Moro Cojo (Figure 5), where the Natural Resources Conservation Service has many successful projects to retard erosion from steep sandy slopes. These sites are too numerous to list and not the first priority for the Moro Cojo Slough plan.

Existing Project Sites in the Moro Cojo Watershed

Project Region (Fig 6)	Landowner	Restoration Status
So. Moro Cojo	Elkhorn Slough Foundation	Began Fall 1996
Moon Glow Marsh	Moon Glow Dairy	Began Fall 1996
Moon Glow Marsh	Pacific Gas and Electric	First year
Mid Moro Cojo	Calcagno family	Completed
Upper Moro Cojo	No. Monterey High School	Began Fall 1996
Castroville Slough	Don Chapin	Second year
Castroville Slough	Jimenez family	Second year
Prunedale area	Jo Guerrero	Completed
So. Moro Cojo	Pacific Gas and Electric	Beginning Fall 1997

Next Sites in the Main Moro Cojo Slough

Project Region (Fig 6)	Landowner	Permission Status
So. Moro Cojo	Catellus Inc.	Mitigation potential
Moon Glow Marsh	Granite Rock Inc.	Acquisition proposed
Moon Glow Marsh	Catellus Inc.	Early negotiation

Final Sites in the Main Moro Cojo Slough

Project Region (Fig 6)	Landowner	Permission Status
So. Moro Cojo	Tottino et al.	+ incentives needed
Dolan Road	Massera family	+ incentives needed
Dolan Road	Long family	+ incentives needed
Mid Moro Cojo	Calcagno family	+ incentives needed
Mid Moro Cojo	Tottino et al.	+ incentives needed
Mid Moro Cojo	Dolan family	+ incentives needed
Castroville Slough	Torres family	+ incentives needed
Castroville Slough	Hurley family	+ incentives needed

10. CONCLUSIONS

The Watershed Institute received a new 319(h) grant to implement wet corridor restoration (i.e. construct water management areas) around the City of Salinas, extending the work in Moro Cojo Slough further into this major demonstration watershed (Figure 4). The grant will help to implement restoration along the Natividad Creek, Gabilan Creek, Carr Lake, Markley Marsh and the Tembladero Slough (called the reclamation ditch within the city) as water management areas for urban and farm drainages. It will also develop landowner incentives for wet corridor restoration on grazing land along the hillsides of the Salinas Valley, working closely with the Natural Resource Conservation Service, the City of Salinas, and Monterey County Water Resources Agency. Throughout these hills the primary task is to gain permission to fence cattle from wet corridors amounting to only small areas of ranches with significant positive impacts on flood storage and other water resource values.

The City of Salinas grant and future success in implementing this watershed restoration plan depend on the unique network of working partnerships between organizations concerned with water reuse. All partners recognize the watershed basis for water planning and management, and the critical need to direct public support into implementation. Retention of surface water, flood protection, water quality, ground water recharge, and biodiversity are directly linked to a healthy watershed. Although the Salinas Valley is one of the most degraded watershed in the state, it may be the best location in the state to implement a successful watershed restoration and reuse program.

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Appendix 1

Moss Landing Harbor and Restoration Plan

APPENDIX 1
Moss Landing Harbor and Watershed Restoration

1. Sedimentation and Chemical Contamination

Moss Landing Harbor is a primary sink for sediment and chemical contaminants transported through the watershed of the Tembladera and Moro Cojo Slough complex and into Monterey Bay. Sediment from the watershed naturally accumulates in the deep harbor channels which must be maintained by periodic dredging. Without this dredging the entrance channel would eventually shoal and the harbor mouth and channels would fill with sediment preventing harbor operations. In this regard the harbor is similar to the deeper channel of the Salinas and Pajaro Rivers and most of the tributary creeks such as the Tembladera Slough, which are channelized by human beings and are periodically excavated to maintain the deep ditches. Natural movement of water and sediment would eventually fill the anthropogenic drainage channels.

The most effective harbor sink for fine sediment is the south channel next to the one lane bridge (Sandholt Road). Organic chemicals and metals bind more easily to finer sediment particles and especially to organic/mineral aggregates. These are trapped in the back harbor. Most of these particles erode from farm land into straight drainage ditches, one ditch to the next. The eroded material and its chemical load are transported into and through the harbor and eventually into Monterey Bay. Some is trapped in the south harbor sink. This is non-point source pollution because it does not come from a single source such as a domestic sewage outfall- a classic point source of pollution. The pollution comes from throughout the watershed.

Moss Landing Harbor is commonly dredged every 3-4 years, along at least a section of the main channel and under docks (Figure 1). This maintenance dredging is often delayed or prevented by the levels of anthropogenic chemicals in the channel sediments, particularly metals and pesticides. Although DDT was banned in 1972, it persists in farm sediments and drainages as well as in the tissues of bay mussels from the south end of Moss Landing Harbor (Figure 2, Map-1). DDT and the most abundant metals in harbor sediments are much higher in the back harbor where water currents are slow and muddy sediment accumulates (Figure 3). The front of the harbor is swept by stronger tidal currents from the entrance channel and the bottom is covered with coarser sands. The high levels of metals and DDT in the back harbor have been present before major dredging operations for several decades (Figure 4, Tables 1-4, Maps 1-2, Oliver and Slattery 1976).

2. Ecological Model of Risk Assessment

Sediment contamination similar to that in Moss Landing Harbor is widespread in harbors throughout the state and county. Existing regulation of dredging operations by the U.S. Army Corp of Engineers and the U.S. Environmental Protection Agency depend on standard procedures that rarely assess local conditions and most important do not evaluate ecological risk. Moss Landing Marine Laboratories has developed a model for assessing ecological risk of dredging and dredge material disposal at Moss Landing Harbor. The model is based on years of extensive ecological research on the impacts of dredging and disposal (Oliver and Slattery 1976 and Oliver et. al 1977) as well as the ecology of natural disturbances to benthic habitats and communities (Oliver et al. 1980, Hulberg and Oliver 1980, Kvitek et al. 1988, Okey 1993, Kim et al. in review).

The risk assessment model can be tested and verified in a cooperative research program during the dredging of the harbor, including a comparison of model results to the usual regulatory approach. There has been general agreement among regional scientists at past meetings about sediment contamination in the Moss Landing Harbor that effective assessment of real ecological risks is the most important step needed in the regulation of dredging and disposal operations. Risk assessment will insure greater protection of the environment while streamlining permit red tape by focusing attention on real problems and their relative risks.

The ecological impacts of Moss Landing Harbor dredging and disposal activities were evaluated in two detailed studies in the 1970's (Oliver and Slattery 1976 and Oliver et. al 1977). The work was funded by the Coastal Engineering Research Center and later by the Waterways Experiment Station under the National Dredged Material Research Program. They provide the scientific background for the selection of the Monterey Submarine Canyon head disposal station and make a detailed ecological risk assessment of various options for dredging operations.

The risk assessment concerns a number of ecological factors that are not evaluated in the usual regulatory process, which is based primarily on information from bioassays, bioaccumulation, and bulk sediment chemistry. In contrast, the ecological risk assessment also uses information on natural patterns of sediment movement, the total volume of sediment involved in a dredging operation, and the natural history of the native benthic fauna, particularly their ability to tolerate and recover from periodic disturbances. It also considers the spatial and temporal scale of the dredging and disposal disturbance in relation to the scale of natural disturbances. In this analysis, ecological risk is minimized by disposal in environments with high incidence of natural disturbances.

Dredged material from Moss Landing Harbor is disposed at the head of Monterey Submarine Canyon, because the risks of significant ecological impacts are low. The canyon head is a natural sedimentary dump, with a seasonal cycle of infilling with sediment and natural organic debris followed by a period of down-canyon slumping and active flushing. The total volume of sediment from the harbor dredging is low compared to the natural deposition and movement of sediment in the canyon. As long as disposal is restricted to periods of canyon flushing, dredged material flows into deep water along a natural sediment channel. The physical and biological environments along the canyon axis or channel experience high natural levels of disturbance from deposition and movement of sediment. As a result, the impacts of dredge disposal are difficult to detect, except for short periods over a small area of sea floor (Oliver and Slattery 1976 and Oliver et. al 1977).

Dredged material often contains higher concentrations of anthropogenic chemicals, especially metals and hydrocarbons, compared to most natural deposits. These chemicals are a major concern of resource managers and permit regulators. They are measured on a per sample basis, a standard weight of sediment. As a result a low sample number can amount to a large quantity of chemicals if the total volume of dredged material is great. A moderate or high sample value can amount to a quite low total chemical content if the volume of dredge material is low, as it is in Moss Landing Harbor. Unfortunately, the total volume of dredged sediment is not properly considered in the regulatory process for assessing the ecological risks of chemicals. If dredged material is mixed with natural deposits, there can be considerable dilution of chemicals making a less toxic concentration. Although no measurements have been made of dredged material after flushing into the natural canyon sedimentary dump, it is unlikely that harbor chemicals can be detected from deeper water after flushing (Oliver and Slattery 1976, Oliver et. al 1977, and also Shepard and Gill 1966, Okey 1993, and Kim et al. in review) .

3. Natural Sediment Movement in the Canyon

The seasonal movement of sediment in the head of Monterey Canyon is similar to the patterns observed in the Scripps and especially the La Jolla Canyons in Southern California (Shepard and Gill 1966, Veter 1995). During the relatively calm months of summer and early fall, the canyon head fills with sediment and drifting organic debris, particularly kelp and green algae. The bottom substrate often becomes anoxic and gas bubbles commonly emerge from the sediment. This decomposition is probably important in producing unstable sediment interfaces permitting rapid down-canyon slumping of large masses of sediment. The primary trigger for mass wasting in the canyon head is bottom currents generated by the first large storm waves in the mid or late fall. The canyon head is commonly flushed in a single storm, causing dramatic changes in canyon topography. The depth of the canyon axis can become many meters deeper, often leaving distinct erosional features including steep channel walls. All fine sediment and organic debris is flushed down canyon, exposing a relatively clean sand bottom. The walls surrounding the axis shoal and move seaward until the first storms arrive, when they are eroded shoreward sending large volumes of sand into the axis of the canyon head and then into deeper water. Later storms move more sand and some organic drift into the canyon head and then into deeper water along the axis. Down canyon movement of sediment from the canyon head is very active from the first fall storms until early or mid spring, the period of strongest wave action from winter storms; but the first storms cause the major changes in canyon topography shifting from the period of accumulation to active flushing. By late spring and summer, sediment and organic debris begin to accumulate again in the canyon head (see Arnal et al. 1973, Oliver and Slattery 1976, Oliver et. al 1977, Okey 1993).

Despite the predictable seasonal flushing of the canyon head and the movement of a large volume of fine sediment and organic debris, transport and deposition of this annual mass of slumping material has not been detected in deeper water (Shepard and Gill 1966, Arnal et al. 1973). The annual mass wasting is undoubtedly a turbidity flow and probably spreads over a relatively large area of the deeper canyon. Turbidity flows settle into turbidites, which are distinct depositional sequences found throughout the canyon. No turbidite has been identified for the annual turbidity flow from the canyon head. Sediment dams are also known from deeper parts of the canyon axis which may stop flows for many years, but the impacts of these dams on down canyon movements from the canyon head are unknown (Shepard and Gill 1966).

Since the natural movement of sediment and debris is difficult to follow beyond the canyon head, it is even less likely to detect the movement and deposition of a smaller volume of dredged material during the period of active down canyon sediment flow (Oliver and Slattery 1976, Oliver et. al 1977).

4. Research Monitoring of Dredging (Testing Risk Assessment)

Moss Landing Harbor is in a unique position to develop a model for ecological risk assessment applicable to other dredging operations as well as sediment disposal from Caltrans activities to maintain coastal highways. The validity of the harbor's risk assessment can be monitored in a research dredging operation and the results compared to conventional regulatory techniques, such as bioassays, bioaccumulation, and bulk sediment chemistry. The research monitoring can be permitted under a memorandum of agreement among the harbor, the U.S. Army Corps of Engineers, and a research institution such as the Moss Landing Marine Laboratories.

The predictions of the risk assessment model can be tested in a field monitoring program. This includes information on chemical concentrations in sediment, volume of dredged material, natural sediment movement in the canyon, dredge material movement in the canyon, chemical concentrations of dredged and natural sediments at the canyon disposal site and in the deeper canyon, and short and long-term ecological impacts of the disposal disturbance.

There are significant inputs of worrisome chemicals to the harbor from the surrounding watershed, primarily from agricultural runoff. Although their presence in the harbor creates a major regulatory problem, the harbor is not responsible for their origin. These chemicals will be reduced most effectively in the harbor by capturing them in water management areas, where the channel or ditch system is converted into a more natural wet corridor. Naturally vegetated wet areas are excellent best large-scale biological filters. The wet corridors are the primary drainages where water flows from the land to the sea along creek and rivers and through marshes. In Monterey Bay, most wet corridors were diked, ditched and drained many decades ago, leaving the present channel-ditch system, which has contributed to highly degraded surface water quality and the sea water intrusion problem in under ground aquifers.

Restoration of the wet corridors, particularly in the Salinas Valley, is the primary goal of the Watershed Institute at California State University Monterey Bay. Such restoration is becoming a main objective of the Watershed Management Initiative for the Salinas Valley prepared by the Central Coast Regional Water Quality Control Board and State Water Resources Control Board; and should become a major objective for the Salinas River Basin Management Plan prepared by the Monterey County Water Resources Agency. The restoration of natural drainages maximizes all of the critical water resource values, including water retention, groundwater recharge, water quality improvement, flood control, biodiversity, and fire protection. However, while upstream watershed restoration will reduce inputs of farm chemicals to Moss Landing Harbor, the Monterey Submarine Canyon alternative continues to be the most ecologically sound option for disposal of dredged material from Moss Landing Harbor.

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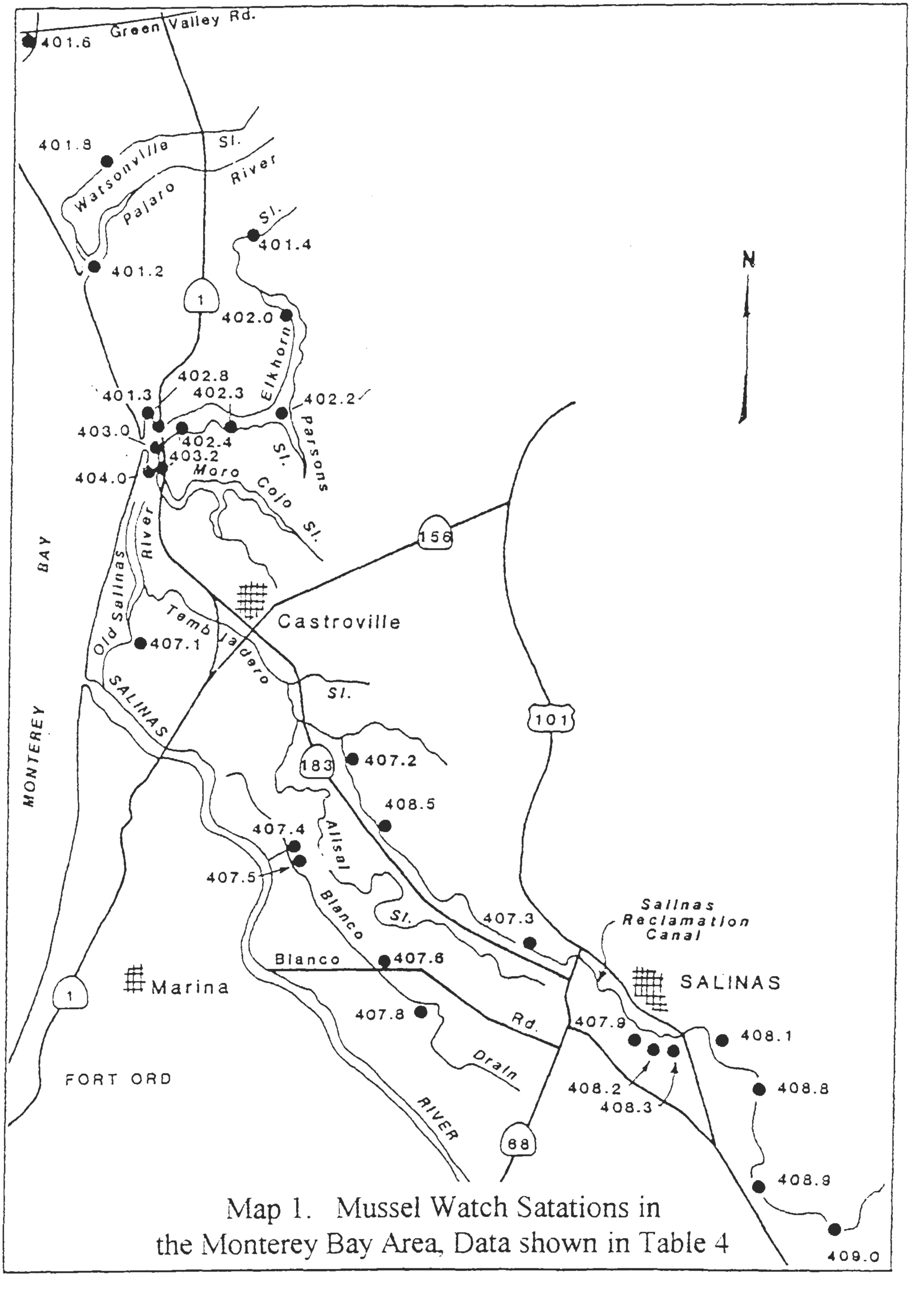


Map 1. Mussel Watch Satations in the Monterey Bay Area, Data shown in Table 4

Map 2d

Locations of Various Sediment Sampling Areas in Moss Landing Harbor, Data in Table 1.

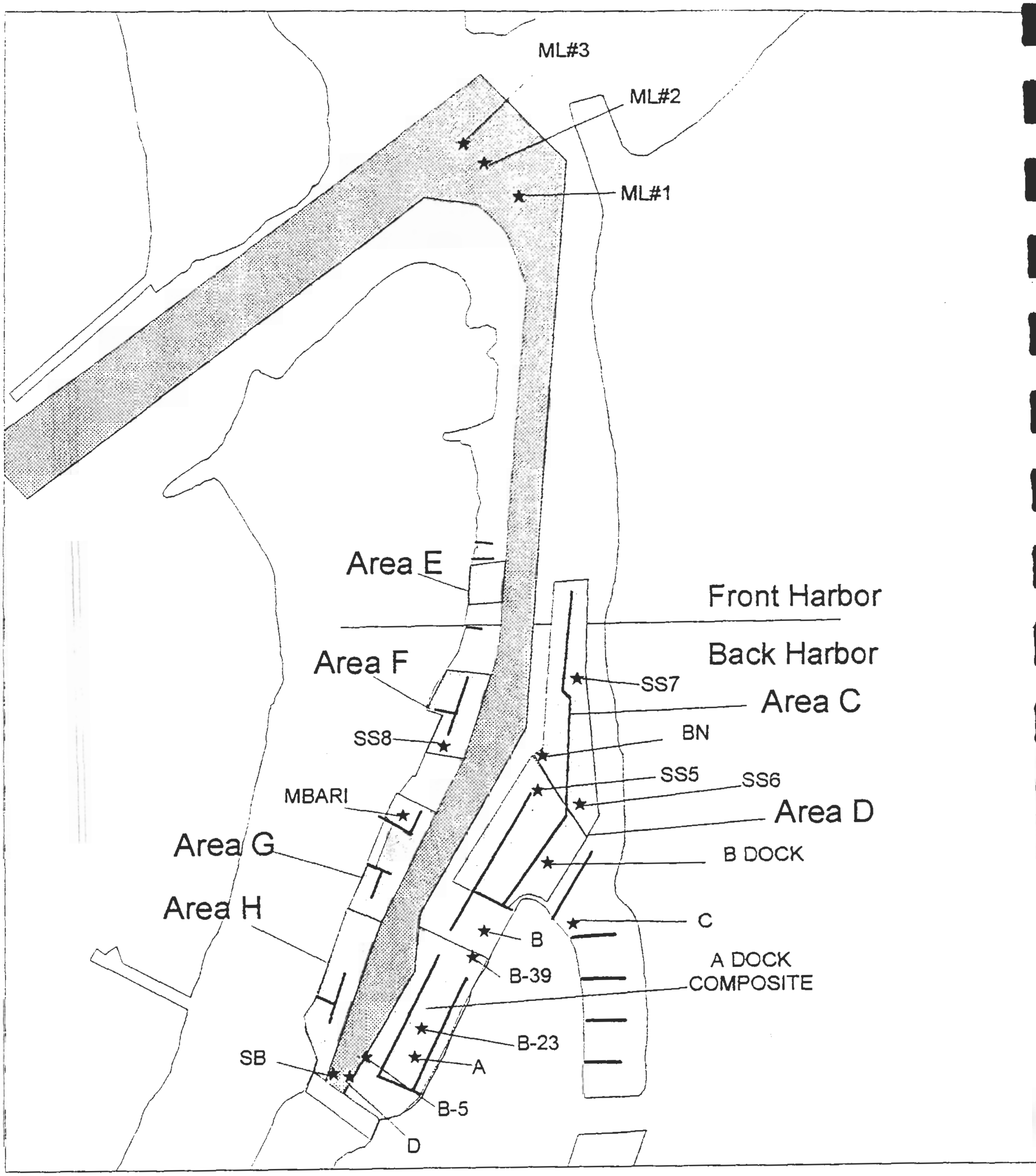


Figure 3: Amounts of Copper, Zinc, and T-DDT in Moss Landing Harbor sediment from the back and mouth regions in 1993.

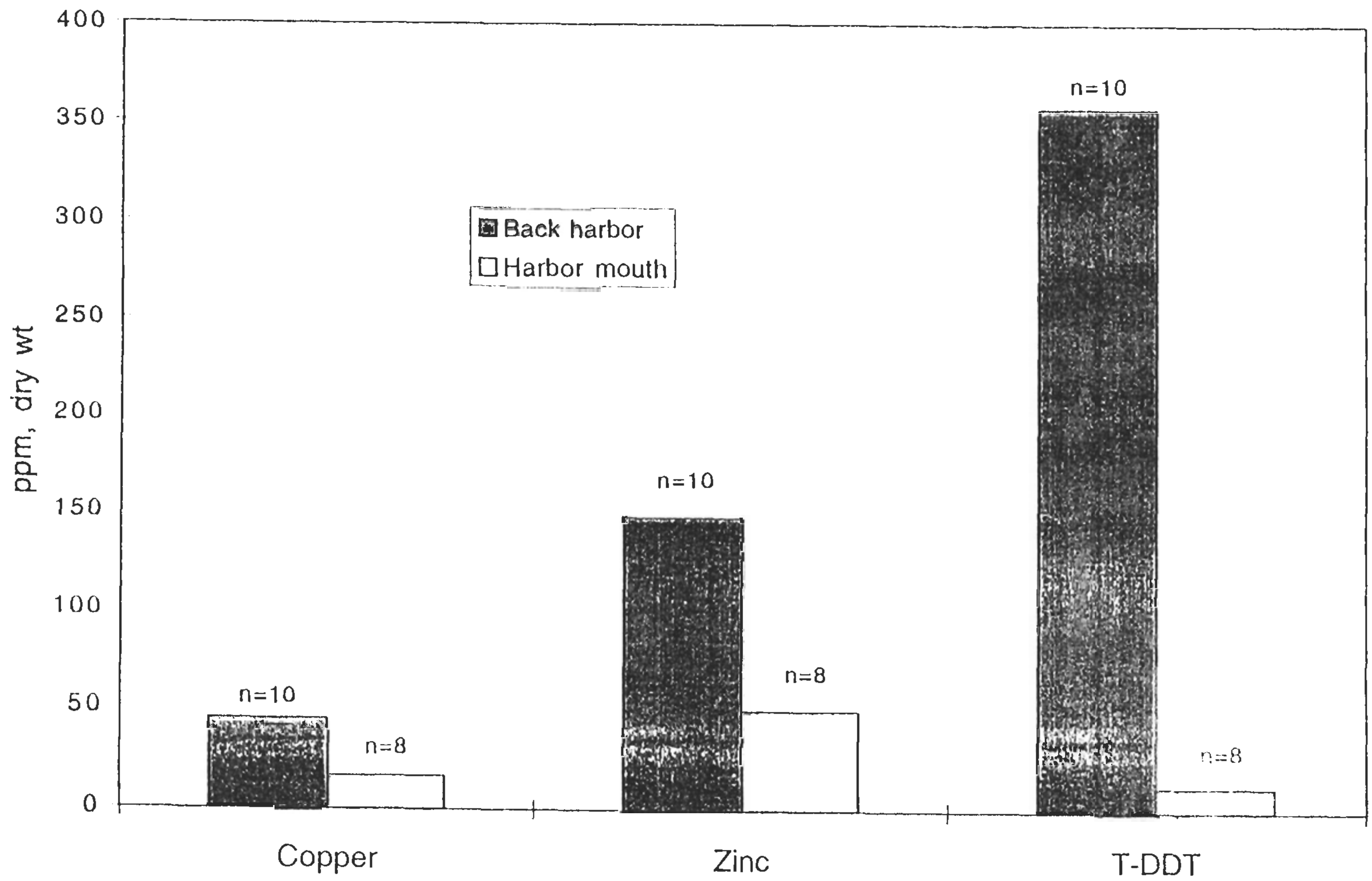
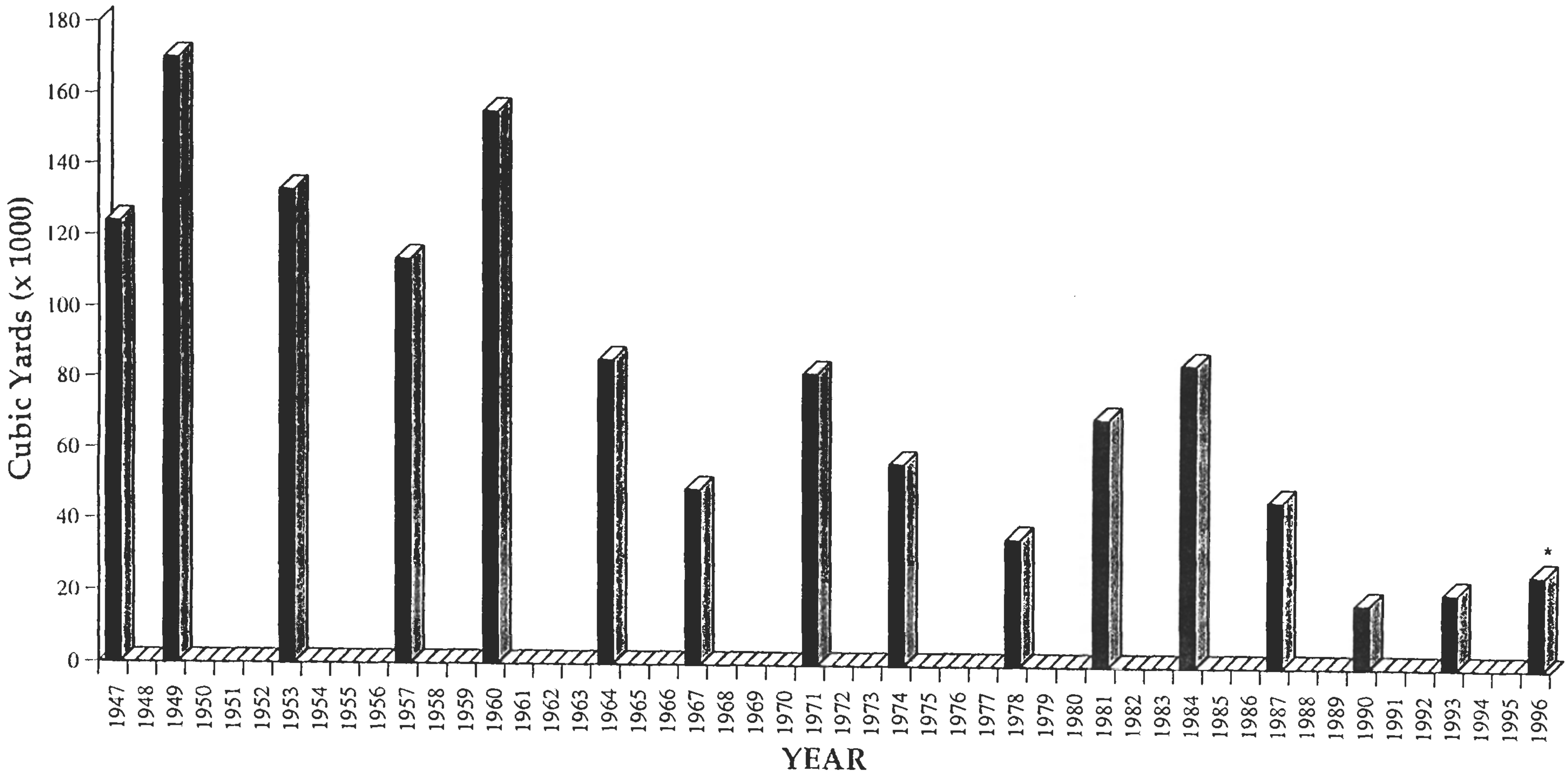


Figure 1.
Amount of Sediment Dredged by U.S. Army Corps of Engineers in Moss Landing Harbor Federal Channel, 1947-1996*



* 1996 shows estimated 26000 yds to be dredged from Federal Channel in Spring 1996 (estimated 24000-28000 cubic yards, L. Steffan memo)

Information Sources

1947-1995: Ted Burge, Operations and Maintenance Project Manager for Moss Landing Harbor District, US Army Corps of Engineers. Pers. comm. using historical dredge records on file at San Francisco USACOE office.

1996: 2/23/96 Memo from Larry Steffan, Harbor Manager, Moss Landing Harbor District.

Figure 2. Total DDT in Bivalve Tissues at Sandholt Bridge- 1982 to 1994.

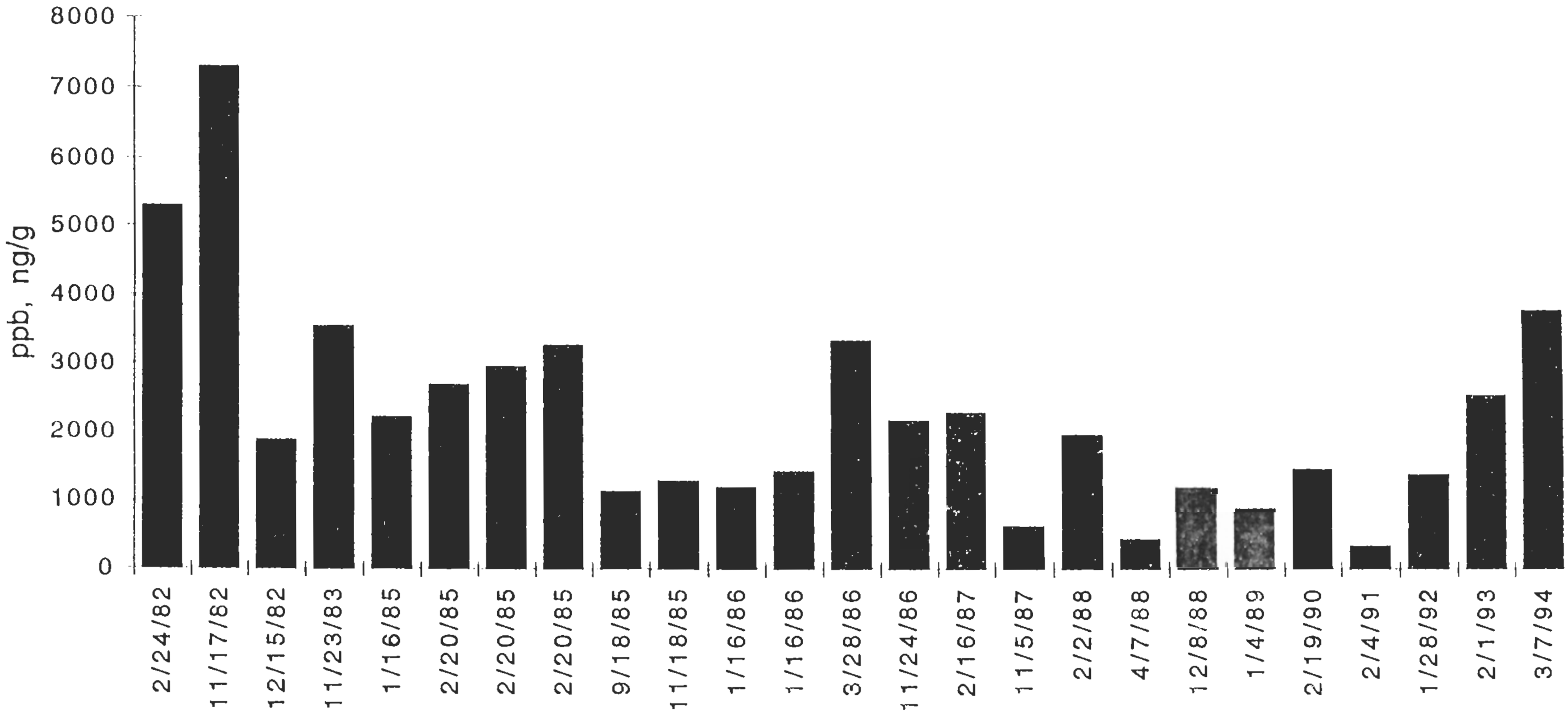
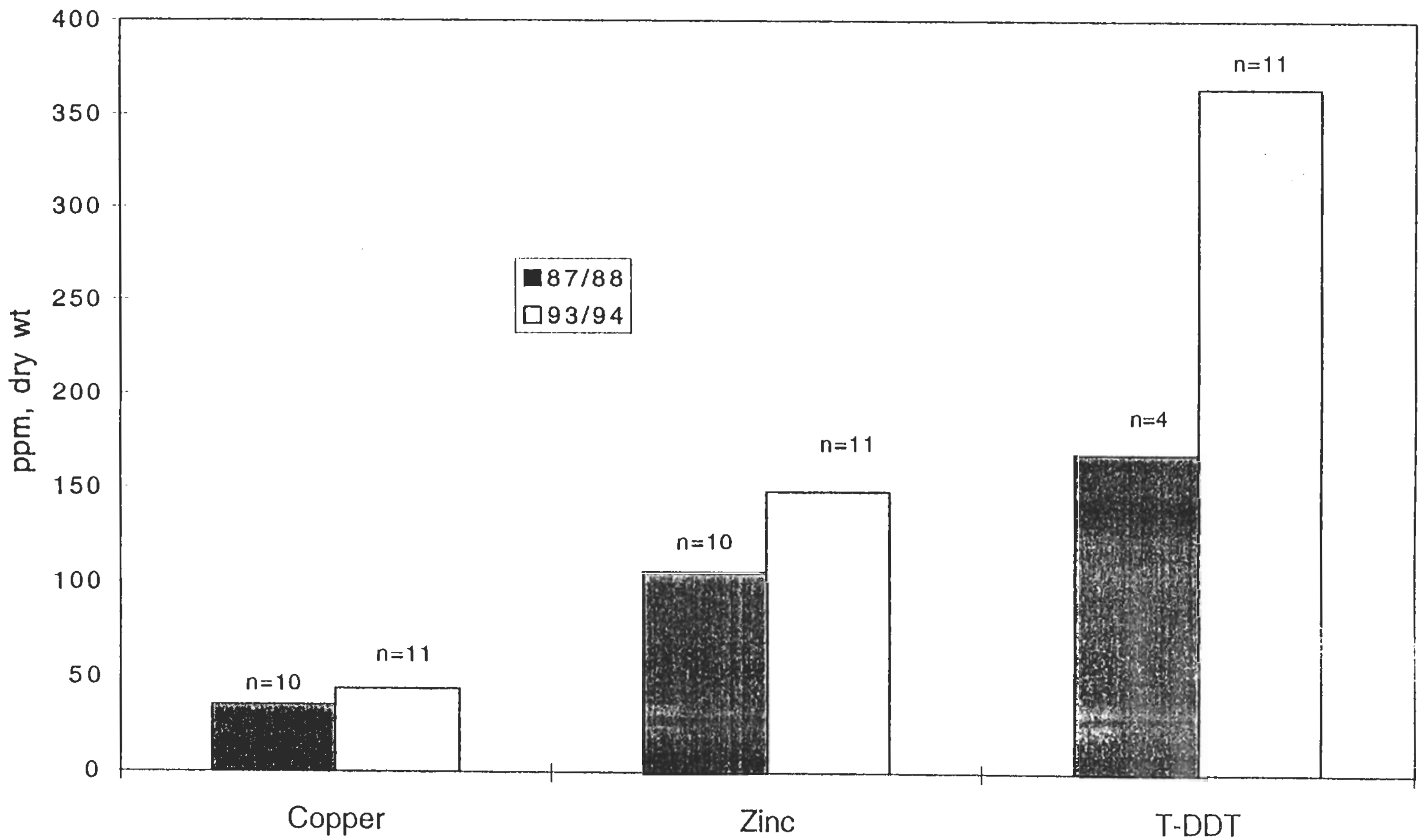
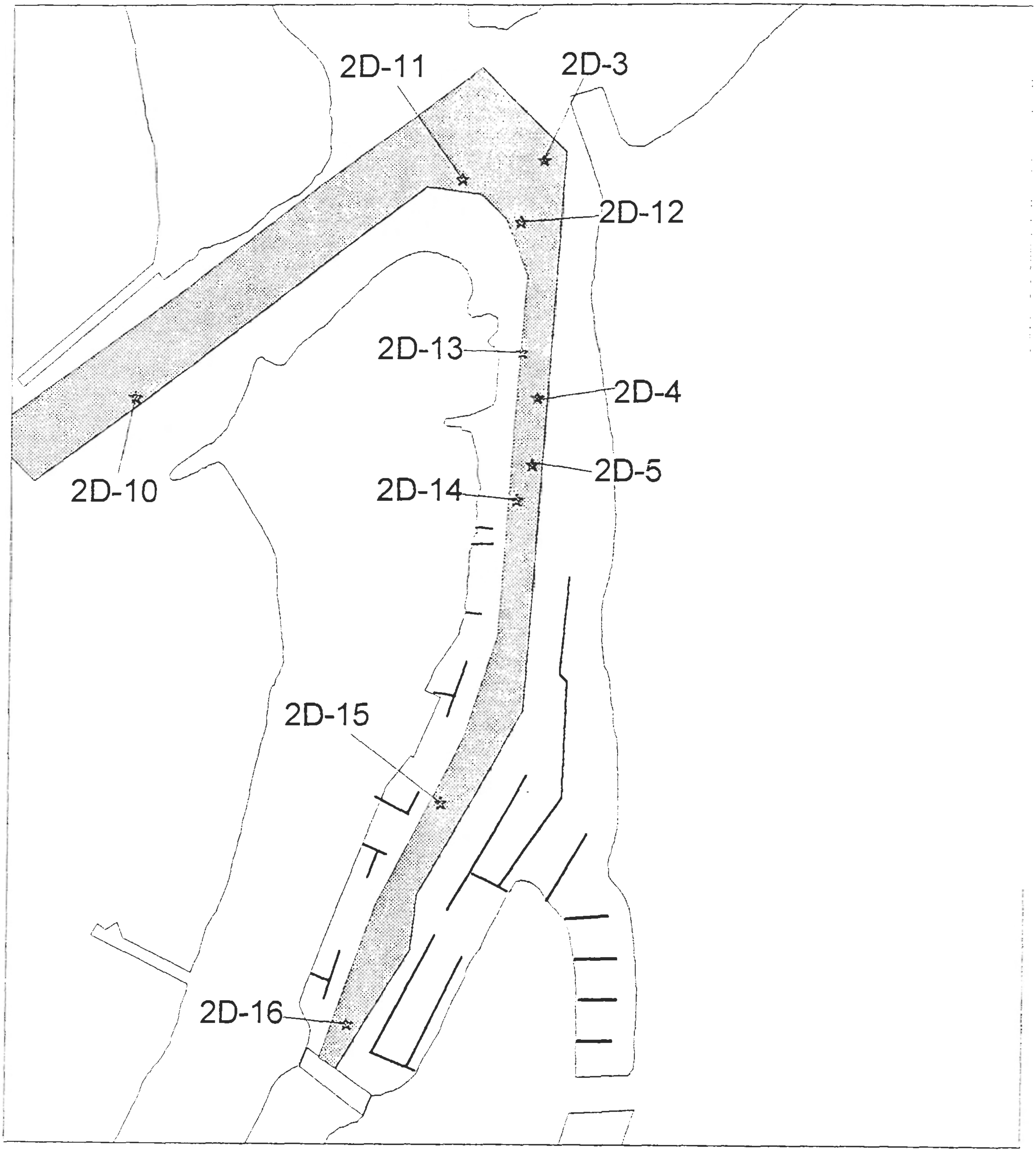


Fig. 2.

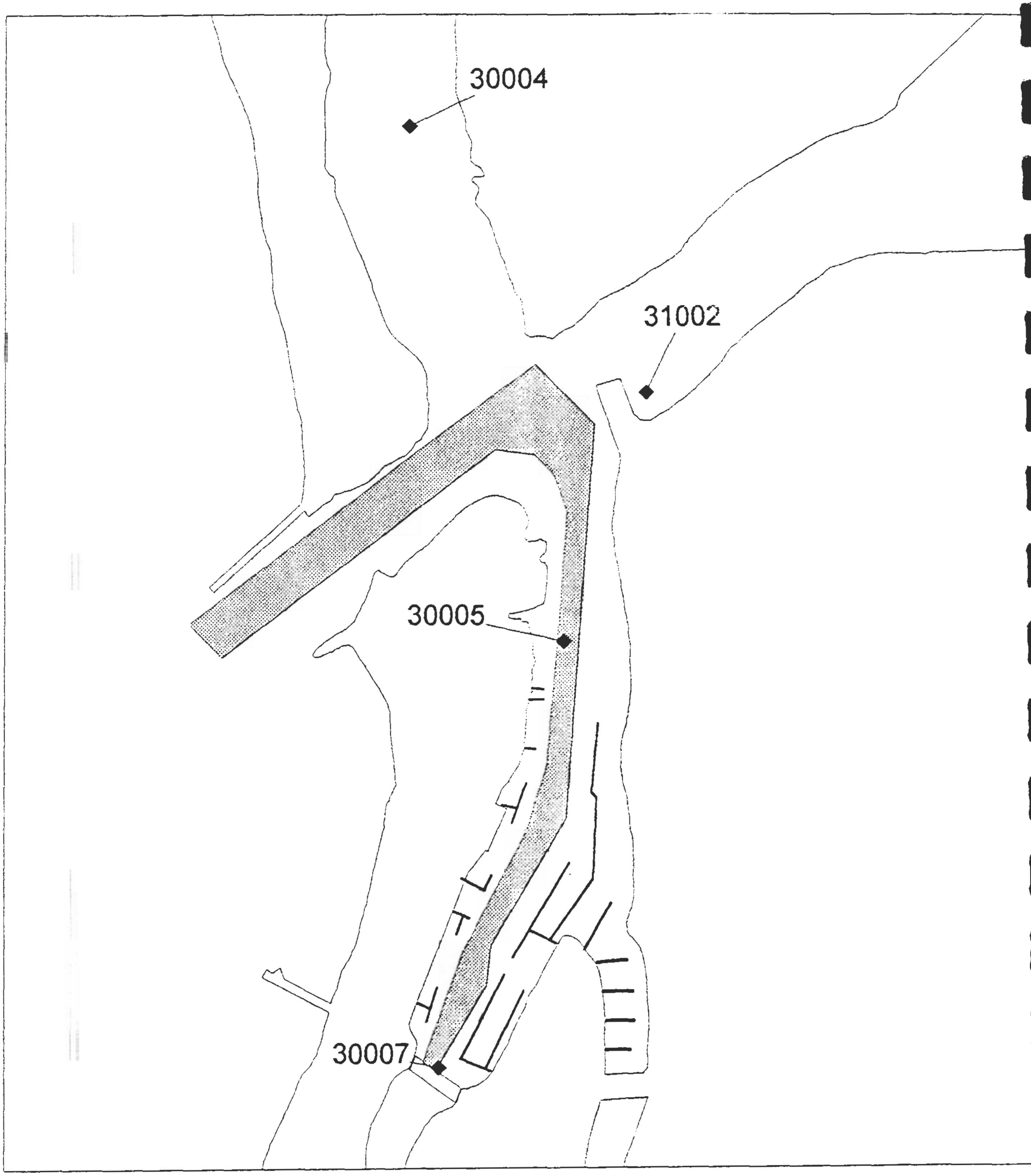
Figure 4. Amounts of Copper, Zinc, and T-DDT in back-harbor sediment in 1987/1988 and 1993/1994.



Map 2a Locations of Various Sediment Sampling Areas in Moss Landing Harbor, Data in Table 1.



Map 2c Locations of Various Sediment Sampling Areas in Moss Landing Harbor, Data in Table 3.



Map 2b Locations of Various Sediment Sampling Areas in Moss Landing Harbor, Data in Table 1.

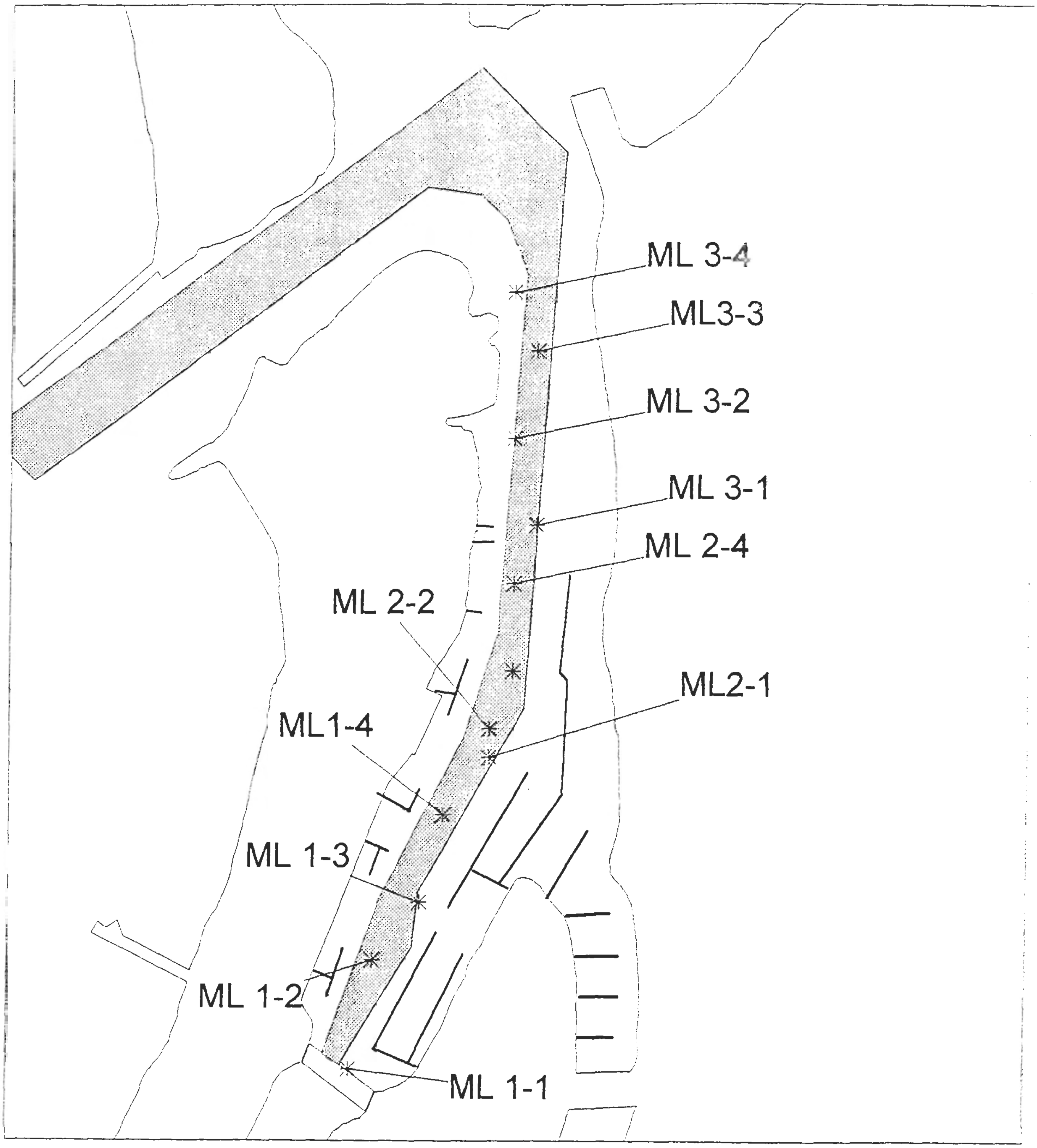


Table 1. Sediment chemistry in Moss Landing Harbor (see Map 2).

STATION #	DATE SAMPLED	TYPE	COPPER (mg/kg dw)	LEAD (mg/kg dw)	ZINC (mg/kg dw)	TDDT (ug/kg dw)	TPCB (ug/kg dw)	PAH (ug/kg dw)	ENDOSULFAN I (ug/kg dw)	ENDOSULFAN II (ug/kg dw)	CHLORDANE (ug/kg dw)	DIELDRIN (ug/kg dw)
A dock composite	12/7/94	sediment	38.00	0.160	150.00	434.0	ND	120	not sampled	not sampled	not sampled	not sampled
ML 1-1	2/93	sediment	39.00	20.000	130.00	296.4	ND	ND	ND	ND	ND	ND
ML 1-2	2/93	sediment	47.00	29.000	160.00	402.3	ND	ND	ND	ND	ND	ND
ML 1-3	2/93	sediment	56.00	14.000	210.00	444.0	ND	ND	ND	ND	ND	ND
ML 1-4	2/93	sediment	48.00	29.000	150.00	355.6	ND	ND	ND	ND	ND	ND
ML 2-1	2/93	sediment	44.00	28.000	140.00	318.7	ND	ND	ND	ND	ND	ND
ML 2-2	2/93	sediment	40.00	28.000	150.00	385.3	ND	ND	ND	ND	ND	ND
ML 2-3	2/93	sediment	40.00	28.000	150.00	440.2	ND	ND	ND	ND	ND	ND
ML 2-4	2/93	sediment	41.00	22.000	110.00	186.0	ND	ND	ND	ND	ND	ND
ML 3-1	2/93	sediment	14.00	11.000	46.00	14.1	ND	ND	ND	ND	ND	ND
ML 3-2	2/93	sediment	14.00	11.000	43.00	20.1	ND	ND	ND	ND	ND	ND
ML#1	2/93	sediment	19.00	13.000	54.00	7.0	ND	ND	ND	ND	ND	ND
ML #2	2/93	sediment	20.00	17.000	60.00	10.7	ND	ND	ND	ND	ND	ND
ML #3	2/93	sediment	6.90	10.000	35.00	2.6	ND	ND	ND	ND	ND	ND
ML 3-4	2/93	sediment	22.00	18.000	73.00	21.7	ND	ND	ND	ND	ND	ND
ML 3-3	2/93	sediment	20.00	8.000	36.00	3.9	ND	ND	ND	ND	ND	ND
ML-3 composite	2/93	sediment	14.00	12.000	45.00	18.6	ND	ND	ND	ND	ND	ND
ML-2 composite	2/93	sediment	41.00	27.000	130.00	390.9	ND	ND	ND	ND	ND	ND
ML-1 composite	2/93	sediment	46.00	17.000	150.00	352.4	ND	ND	ND	ND	ND	ND
BS	12/15/88 (sample received)	sediment	27.00	8.400	97.00	151.0	ND		ND	ND	ND	8.5
BN	12/15/88 (sample received)	sediment	27.00	9.400	78.00	110.0	ND		ND	ND	ND	7.1
F	12/15/88 (sample received)	sediment	24.00	12.000	99.00	220.0	ND		4	ND	ND	12
D	12/15/88 (sample received)	sediment	26.00	11.000	79.00	191.0	ND		5.9	ND	ND	9.5
1	7/29/88	sediment	5.20	6.800	36.00	not sampled	ND		ND	ND		ND
2	7/29/88	sediment	5.90	9.200	33.00	not sampled	ND		ND	ND		ND
3	7/29/88	sediment	14.00	16.000	61.00	not sampled	ND		ND	ND		ND
4	7/29/88	sediment	31.00	18.000	120.00	not sampled	ND		ND	ND		ND
5	7/29/88	sediment	32.00	78.000	190.00	not sampled	ND		ND	ND		ND
6	7/29/88	sediment	26.00	55.000	100.00	not sampled	ND		ND	ND		ND
Area H	12/29/87 (sample received)	sediment	46.00	31.000	140.00	not sampled	not sampled		Endosulfan ND			
Area G	12/29/87 (sample received)	sediment	57.00	35.000	170.00	not sampled	not sampled		Endosulfan ND			
Area F	12/29/87 (sample received)	sediment	44.00	27.000	130.00	not sampled	not sampled		Endosulfan ND			
Area E	12/29/87 (sample received)	sediment	44.00	26.000	110.00	not sampled	not sampled		Endosulfan = 2			
Area D	12/29/87 (sample received)	sediment	29.00	11.000	77.00	not sampled	not sampled		Endosulfan ND			
Area C	12/29/87 (sample received)	sediment	30.00	13.000	77.00	not sampled	not sampled		Endosulfan ND			
SB	6/10/87	sediment	3.00	1.700	<1	not sampled	not sampled					
B 5	3/28/86	sediment	26.00	22.000	160.00	<0.01	not sampled		<0.01	<0.01		
B 23	3/28/86	sediment	29.00	26.000	170.00	<0.01	not sampled		<0.01	<0.01		
B 39	3/28/86	sediment	25.00	26.000	170.00	<0.01	not sampled		<0.01	<0.01		
2D-10	84	sediment	0.005 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
2D-11	84	sediment	0.005 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
2D-12	84	sediment	0.006 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
2D-13	84	sediment	0.003 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
2D-14	84	sediment	0.008 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
2D-15	84	sediment	0.006 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
2D-16	84	sediment	0.005 mg/l	0.001 mg/l	0.001 mg/l	not sampled	ND		Endosulfan ND			
SS8	7/21/78	sediment	430.00	11.000	110.00	not sampled						
SS8	7/21/78	sediment	57.00	25.000	230.00	not sampled						
2D-3	2/1/78	sediment	not sampled	18.000	76.00	not sampled						
2D-4	2/1/78	sediment	not sampled	13.000	55.00	not sampled						
2D-5	2/1/78	sediment	not sampled	26.000	88.00	not sampled						
SS7	8/5/77	sediment	39.00	31.000	120.00	not sampled						
SS6	8/5/77	sediment	410.00	30.000	138.00	not sampled						
SS5	8/5/77	sediment	22.00	290.000	67.00	not sampled						
Dock A	11/14/75	sediment	260.00	16.000	140.00	not sampled						
Dock B	11/14/75	sediment	80.00	18.000	330.00	not sampled						
A	10/1/75	sediment	not sampled	32.500	114.00	not sampled						
B	10/1/75	sediment	not sampled	14.800	214.00	not sampled						
C	10/1/75	sediment	not sampled	24.200	94.00	not sampled						

Table 2. Description of sediment chemistry stations from Table 1.

STATION #	DATE SAMPLED	LATITUDE	LONGITUDE	SOURCE	STATION LOCATION
A dock composite	12/7/94	see map	see map	Moss Landing Harbor District, Toxscan 11507	Moss landing harbor main channel
ML 1-1	2/93	36.8000555	-121.78639	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 1-2	2/93	36.8011111	-121.78611	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 1-3	2/93	36.801666	-121.78555	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 1-4	2/93	36.8025	-121.78528	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 2-1	2/93	36.8030555	-121.78472	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 2-2	2/93	36.8033333	-121.78472	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 2-3	2/93	36.8038888	-121.78445	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 2-4	2/93	36.8047222	-121.78444	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 3-1	2/93	36.8052777	-121.78417	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 3-2	2/93	36.8061111	-121.78444	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML#1	2/93	see map	see map	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML #2	2/93	see map	see map	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML #3	2/93	see map	see map	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 3-4	2/93	36.8075	-121.78444	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML 3-3	2/93	36.8069444	-121.78417	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML-3 composite	2/93	see map	see map	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML-2 composite	2/93	see map	see map	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
ML-1 composite	2/93	see map	see map	San Francisco Army Corps of Engineers, Toxscan T-9468	Moss landing harbor main channel
BS	12/15/88 (sample received)	see map	see map	Moss Landing Harbor District, Toxscan T88-3350	B dock south end
BN	12/15/88 (sample received)	see map	see map	Moss Landing Harbor District, Toxscan T88-3350	B dock north end
F	12/15/88 (sample received)	see map	see map	Moss Landing Harbor District, Toxscan T88-3350	F dock in front of MBARI
D	12/15/88 (sample received)	see map	see map	Moss Landing Harbor District, Toxscan T88-3350	Dock in front of sandholt bridge
1	7/29/88	see map	see map	California Costal Commission, US Army Corps of Engineers	Moss landing harbor main channel
2	7/29/88	see map	see map	California Costal Commission, US Army Corps of Engineers	Moss landing harbor main channel
3	7/29/88	see map	see map	California Costal Commission, US Army Corps of Engineers	Moss landing harbor main channel
4	7/29/88	see map	see map	California Costal Commission, US Army Corps of Engineers	Moss landing harbor main channel
5	7/29/88	see map	see map	California Costal Commission, US Army Corps of Engineers	Moss landing harbor main channel
6	7/29/88	see map	see map	California Costal Commission, US Army Corps of Engineers	Moss landing harbor main channel
Area H	12/29/87 (sample received)	see map	see map	Harding-Lawson Associates, Toxscan 2074-8	Area around F dock
Area G	12/29/87 (sample received)	see map	see map	Harding-Lawson Associates, Toxscan 2074-8	Area around Bayfresh dock
Area F	12/29/87 (sample received)	see map	see map	Harding-Lawson Associates, Toxscan 2074-8	Area around E dock
Area E	12/29/87 (sample received)	see map	see map	Harding-Lawson Associates, Toxscan 2074-8	Area near K dock
Area D	12/29/87 (sample received)	see map	see map	Harding-Lawson Associates, Toxscan 2074-8	Area near South end of B dock
Area C	12/29/87 (sample received)	see map	see map	Harding-Lawson Associates, Toxscan 2074-8	Area near North end of B dock
SB	6/10/87	see map	see map	Regional Water Quality Control Board	Sandholt bridge discharge pipe
B 5	3/28/86	see map	see map	Moss Landing Harbor District, Marine Bioassay Labratories	A dock berth 5
B 23	3/28/86	see map	see map	Moss Landing Harbor District, Marine Bioassay Labratories	A dock berth 23
B 39	3/28/86	see map	see map	Moss Landing Harbor District, Marine Bioassay Labratories	A dock berth 39
2D-10	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
2D-11	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
2D-12	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
2D-13	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
2D-14	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
2D-15	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
2D-16	84	see map	see map	Moss Landing Harbor District, US Army Corps of Engineers	Moss landing harbor main channel
SS8	7/21/78	see map	see map	Moss Landing Harbor District, Analytical Chemists & Bacteriologists	Junction at East end of D dock
SS8	7/21/78	see map	see map	Moss Landing Harbor District, Analytical Chemists & Bacteriologists	Junction at East end of D dock
2D-3	2/1/78	see map	see map	US Army Corps of Engineers	Moss landing harbor main channel
2D-4	2/1/78	see map	see map	US Army Corps of Engineers	Moss landing harbor main channel
2D-5	2/1/78	see map	see map	US Army Corps of Engineers	Moss landing harbor main channel
SS7	8/5/77	see map	see map	Moss Landing Harbor District, Analytical Chemists & Bacteriologists	North end of C dock
SS6	8/5/77	see map	see map	Moss Landing Harbor District, Analytical Chemists & Bacteriologists	Bend in B dock
SS5	8/5/77	see map	see map	Moss Landing Harbor District, Analytical Chemists & Bacteriologists	North end of B dock
Dock A	11/14/75	see map	see map	Analytical Chemists & Bacteriologists	Dock A
Dock B	11/14/75	see map	see map	Analytical Chemists & Bacteriologists	Dock B
A	10/1/75	see map	see map	R. Hurley	A dock
B	10/1/75	see map	see map	R. Hurley	Between A & B dock
C	10/1/75	see map	see map	R. Hurley	C dock

Table 3

Selected Heavy Metals and Organic Contaminants in Sediment sampled by the Bay Protection and Toxic Cleanup Progran in and Around Moss Landing Harbor in 1992. (see Map)

STA_#	STATION NAME	DATE	COPPER	LEAD	MERCURY	ZINC	TBT		T_CHLOR	T_DDT	DIELDRIN	T_ENDO	T_PCB	T_PAH
			ug/g dry wt.						ng/g dry wt.					
30004	M.L. YACHT HARBOR	12/21/92	35.0	20.0	0.057	100.0	0.11		0.75	25.8	2.0	2.0	4.95	885.00
30005	M.L. SOUTH HARBOR	12/21/92	22.0	13.0	0.063	78.0	0.03		0.75	12.4	0.0	0.0	15.60	272.00
30006	PAJARO RIVER ESTUARY	12/21/92	15.0	10.2	0.039	66.0	0.48		0.75	10.5	0.8	0.8	0.00	126.80
30007	SANDHOLT BRIDGE	12/21/92	58.0	26.6	0.100	190.0	0.03		2.45	165.8	6.2	19.5	12.90	1111.70
30019	MORO COJO SLOUGH	12/22/92	43.0	25.6	0.096	180.0	0.11		0.75	22.7	1.1	1.1	4.95	212.50
30023	BENNETT SL./ESTUARY	12/22/92	26.0	14.0	0.053	93.0	0.02		3.05	47.5	7.7	7.7	0.00	72.10
30028	ELKHORN SL. PORTRERO REF.	12/18/92	18.0	16.0	0.046	97.0	0.00		0.75	59.9	3.8	7.7	5.40	373.40
31002	HIGHWAY 1 BRIDGE- REF	10/23/92	11.0	11.6	0.036	53.0	0.00		0.75	4.3	0.0	0.0	6.70	140.50

Table 4

Selected Heavy Metal and Organic Contaminants in Bivalve Tissue
Sampled by the Mussel Watch Program (See map 1)

STA_#	STATION NAME	DATE	TYPE	COPPER	LEAD	MERCURY	ZINC	TBT	T_CHLOR	T_DDT	DIELDRIN	T_ENDO	T_PCB	T_PAH
				ug/g dry wt					ng/g dry wt					
404.0	Sandholdt Bridge	2/16/87	RBM	6.870	0.920	0.201	185.94	-9.0	132.0	2274.0	190.0	2080.0	400.0	
404.0	Sandholdt Bridge	11/5/87	RBM					-9.0	31.2	624.0	23.0	27.0	140.0	
404.0	Sandholdt Bridge	2/2/88	RBM					-9.0	111.0	1944.0	52.0	340.0	620.0	
404.0	Sandholdt Bridge	4/7/88	RBM	8.370	2.469	0.229	382.96	-9.0	15.7	431.5	37.0	560.0	190.0	
404.0	Sandholdt Bridge	12/8/88	RBM	10.000	0.937	0.237	236.68	-9.0	39.3	1170.5	37.0	160.0	210.0	
404.0	Sandholdt Bridge	1/4/89	TCM	11.316	0.940	0.268	355.10	-9.0	26.5	876.8	60.0	290.0	220.0	
404.0	Sandholdt Bridge	2/27/89	RBM	9.430	0.875	0.262	277.33							
404.0	Sandholdt Bridge	4/6/89	RBM	9.060	1.130	0.226	267.33							
404.0	Sandholdt Bridge	2/19/90	TCM	10.550	2.010	0.274	221.01	-9.0	33.5	1443.3	91.5	439.0	237.8	
404.0	Sandholdt Bridge	2/4/91	TCM	11.000	1.700	0.190	200.00	-9.0	24.4	331.6	13.0	4.6	85.0	1080
404.0	Sandholdt Bridge	1/28/92	TCM	11.000	1.100	0.160	160.00	-9.0	20.6	1364.0	190.0	221.2	200.0	1021
404.0	Sandholdt Bridge	2/1/93	TCM	11.000	1.600	0.210	210.00	-9.0	93.5	2515.0	300.0	298.0	240.0	738
404.0	Sandholdt Bridge	3/7/94	TCM	11.000	1.600	0.260	270.00	-9.0	100.7	3745.0	210.0	133.0	180.0	0.559
405.0	Espinosa Slough	11/28/83	TFC					-9.0	744.0	21051.0	1500.0	24500.0	1100.0	
405.2	Old Salinas River 2	1/27/92	SED	6.700	12.000	-8.000	40.00	-9.0	-8.0	4.6	-8.0	-8.0	-8.0	
405.2	Old Salinas River 2	3/16/92	TFC	47.000	0.260	0.140	0.74							
405.2	Old Salinas River 2	3/10/93	TFC	0.000				-9.0	22.5	221.5	27.0	13.0	130.0	
405.3	Old Salinas River 1	1/27/92	SED	11.000	14.000	-8.000	52.00	-9.0	-8.0	21.3	2.3	4.6	-8.0	
405.3	Old Salinas River 1	3/16/92	TFC	66.000	0.350	0.160	120.00	-9.0	55.2	6760.0	690.0	258.0	390.0	
405.3	Old Salinas River 1	3/10/93	TFC					-9.0	248.7	4080.0	640.0	631.0	460.0	
405.4	Old Salinas River Channel 1	11/28/83	TFC					-9.0	326.8	15510.0	450.0	10500.0	980.0	
405.6	Salinas River Lag 1	1/27/92	SED	16.000	11.000	-8.000	78.00	-9.0	-8.0	4.0	0.7	-8.0	-8.0	
405.6	Salinas River Lag 1	3/16/92	TFC	73.000	0.160	0.200	99.00							
405.6	Salinas River Lag 1	3/10/93	TFC					-9.0	20.3	245.2	34.0	18.6	130.0	
405.7	Salinas River Lag 2	1/27/92	SED	50.000	32.000	0.130	160.00	-9.0	6.9	273.8	23.0	89.8	38.0	
405.7	Salinas River Lag 2	3/16/92	TFC	82.000	1.500	0.160	150.00	-9.0	206.2	11487.0	950.0	1129.0	622.0	
405.8	Salinas River Lagoon	11/28/83	TFC					-9.0	336.0	8904.0	150.0	720.0	930.0	
406.0	Westley Station	9/9/83	RFC					-9.0	237.0	7149.0	14.0	680.0	770.0	
406.0	Westley Station	1/4/89	RFC					-9.0	4.8	114.1	7.6	8.1	30.0	
406.5	Tembladero Slough	3/10/93	TFC					-9.0	229.5	4109.0	700.0	519.0	500.0	
407.1	Moss Landing/Ag Drain/Old River	10/24/84	TFC	23.930	0.600	0.152	111.40	-9.0	44.6	2089.0	230.0	1870.0	170.0	
407.2	Moss Landing/Ag Drain/Espinosa	10/24/84	TFC	22.567	1.130	0.126	151.60	-9.0	612.0	5867.0	1800.0	3030.0	680.0	
407.2	Moss Landing/Ag Drain/Espinosa	12/11/86	TFC					-9.0	160.0	3691.0	910.0	2680.0	500.0	
407.3	Moss Landing/Ag Drain/Davis Rd	12/5/85	TFC					-9.0	179.0	944.0	510.0	320.0	-8.0	
407.3	Moss Landing/Ag Drain/Davis Rd	12/11/86	TFC					-9.0	705.0	1837.0	840.0	407.0	200.0	
407.4	Blanco Pump/West	10/24/84	TFC	27.330	0.567	-9.000	117.06	-9.0	484.0	12940.0	680.0	300.0	2100.0	
407.4	Blanco Pump/West	12/5/85	TFC					-9.0	188.3	5082.0	650.0	620.0	1200.0	
407.4	Blanco Pump/West	3/10/93	TFC					-9.0	173.3	6201.0	1300.0	174.0	380.0	
407.5	Blanco Pump/East	10/24/84	TFC	24.967	0.633	0.096	160.30	-9.0	993.0	51630.0	2500.0	239.0	4000.0	
407.5	Blanco Pump/East	12/6/85	TFC					-9.0	329.0	17440.0	1200.0	217.0	1600.0	
407.5	Blanco Pump/East	12/11/86	TFC					-9.0	673.7	9047.5	2100.0	100.0	1100.0	
407.6	Moss Landing/Ag Drain/Blanco dstr	10/24/84	TFC	16.833	0.267	-9.000	146.83	-9.0	369.3	22600.0	4500.0	276.0	740.0	
407.8	Blanco/Hitchcock	12/5/85	TFC					-9.0	307.7	9960.0	1700.0	98.0	640.0	
407.8	Blanco/Hitchcock	12/11/86	TFC					-9.0	382.0	24821.0	1700.0	255.0	2600.0	
407.9	Salinas Sewage Treatment Plant	11/20/85	TFC					-9.0	195.4	1079.0	620.0	654.0	240.0	
408.1	Canal Airport	11/20/85	TFC					-9.0	71.0	927.8	270.0	1200.0	120.0	
408.2	Produce Wash/Downstream/West	11/20/85	TFC					-9.0	276.6	2365.0	820.0	1160.0	450.0	
408.3	Produce Wash/Downstream/East	11/20/85	TFC					-9.0	303.9	2280.0	950.0	1270.0	410.0	
408.5	Associated Chemicals	12/5/85	TFC					-9.0	366.0	4105.0	770.0	4800.0	410.0	
408.8	Salinas/Reclamation Canal 2	11/20/85	TFC					-9.0	252.0	7098.0	1800.0	2370.0	1110.0	
408.9	Salinas/Reclamation Canal 3	11/20/85	TFC					-9.0	131.0	3534.0	1400.0	707.0	330.0	
408.9	Salinas/Reclamation Canal 3	12/11/86	TFC					-9.0	374.0	18140.0	2000.0	640.0	5000.0	
408.9	Salinas/Reclamation Canal 3	2/3/88	TFC					-9.0	382.0	12490.0	2400.0	864.0	1200.0	
409.0	Salinas/Reclamation Canal 4	11/20/85	TFC					-9.0	255.1	8544.0	1700.0	600.0	700.0	
409.0	Salinas/Reclamation Canal 4	12/11/86	TFC					-9.0	171.0	29539.0	2800.0	309.0	1500.0	
409.0	Salinas/Reclamation Canal 4	2/3/88	TFC					-9.0	1591.0	28410.0	4400.0	760.0	920.0	

Type=Sample Type: RBM=Resident Mussel Tissue, TCM=Transplant Mussel Tissue,
TFC= Transplant Freshwat [illegible]

Table 4

Selected Heavy Metal and Organic Contaminants in Bivalve Tissue
Sampled by the Mussel Watch Program (See map 1)

STA_#	STATION NAME	DATE	TYPE	COPPER	LEAD	MERCURY	ZINC	TBT	T_CHLOR	T_DDT	DIELDRIN	T_ENDO	T_PCB	T_PAH
				ug/g dry wt					ng/g dry wt					
401.3	Moss Landing /Yacht Harbor	3/29/84	RBM	5.767	1.033	0.345	150.00							
401.3	Moss Landing/Yacht Harbor	11/28/83	RBM	10.767	0.967	0.495	159.70	-9.0	266.5	3719.0	280.0	10600.0	350.0	
401.3	Moss Landing/Yacht Harbor	1/29/87	TCM	9.690	1.390	0.256	138.47	3970.0	39.0	466.9	200.0	383.0	100.0	
401.3	Moss Landing/Yacht Harbor	1/4/89	TCM					-9.0	24.3	251.1	100.0	216.0	80.0	
401.4	Elkhorn Slough	11/17/82	TCM					-9.0	-9.0	702.6	-9.0	430.0	-9.0	
401.4	Elkhorn Slough	11/23/83	TCM					-9.0	54.0	1154.0	160.0	1830.0	79.0	
401.5	Watsonville Slough/Bridge	2/2/88	TFC					-9.0	313.6	3598.0	750.0	580.0	130.0	
401.5	Watsonville Slough/Bridge	3/10/93	TFC					-9.0	503.7	10802.0	1700.0	411.0	270.0	
401.6	Harkins Slough Bridge	11/26/86	TFC					-9.0	66.8	349.0	36.0	100.0	73.0	
401.6	Harkins Slough Bridge	2/2/88	TFC					-9.0	157.0	504.0	29.0	20.0	-8.0	
401.8	San Andreas Road	12/6/85	TFC					-9.0	344.0	8450.0	1900.0	492.0	380.0	
401.8	San Andreas Road	11/26/86	TFC					-9.0	275.2	12047.0	2700.0	700.0	170.0	
401.8	San Andreas Road	2/3/88	TFC					-9.0	237.2	4856.0	1400.0	406.0	180.0	
402.0	Elkhorn Slough/Duck Club	2/24/82	RBM					-9.0	58.3	1048.0	46.0	260.0	91.0	
402.0	Elkhorn Slough/Duck Club	3/29/84	RBM	7.867	1.467	0.348	307.93							
402.1	Azevedo Pond	2/25/93	TCM	10.000	2.700	0.230	210.00	-9.0	52.5	1052.0	360.0	94.8	96.0	
402.2	Parson's Slough	11/27/82	TCM					-9.0	-9.0	604.0	-9.0	290.0	-9.0	
402.2	Parson's Slough	11/23/83	TCM					-9.0	25.8	432.5	84.0	1700.0	67.0	
402.2	Parson's Slough	1/15/85	TCM					-9.0	18.8	225.9	30.0	670.0	38.0	
402.2	Parson's Slough	1/16/86	RBM					-9.0	11.5	228.8	11.0	100.0	58.0	
402.2	Parson's Slough	2/2/87	TCM					-9.0	65.0	92.9	30.0	363.0	35.0	
402.2	Parson's Slough	3/2/88	TCM					-9.0	17.0	124.6	32.0	260.0	55.0	
402.2	Parson's Slough	1/4/89	TCM					-9.0	16.0	91.8	27.0	325.0	39.0	
402.2	Parson's Slough	2/25/93	TCM	12.000	1.900	0.230	200.00	-9.0	53.7	857.0	190.0	141.8	120.0	
402.3	Elkhorn Slough/Pacific Maricultur	3/26/79	RBM					-9.0	-9.0	423.0	-9.0	-9.0	180.0	
402.3	Elkhorn Slough/Pacific Maricultur	12/20/79	TCM	6.700	3.867	0.103	126.66							
402.3	Elkhorn Slough/Pacific Maricultur	6/6/80	RBM	5.600	1.700	0.138	63.33							
402.3	Elkhorn Slough/Pacific Maricultur	2/13/81	RBM					-9.0	33.4	701.3	29.0	170.0	210.0	
402.3	Elkhorn Slough/Pacific Maricultur	2/7/84	OYS					-9.0	19.8	907.7	5.8	85.0	160.0	
402.3	Elkhorn Slough/Pacific Maricultur	3/20/85	OYS					-9.0	30.1	452.0	20.0	600.0	120.0	
402.3	Elkhorn Slough/Pacific Maricultur	1/4/89	TCM					-9.0	16.4	119.2	35.0	162.0	36.0	
402.4	Elkhorn Slough/PG & E	11/27/82	TCM					-9.0	-9.0	716.0	-9.0	250.0	-9.0	
402.5	Elkhorn Slough/Tidal Pond	2/25/93	TCM	9.000	1.200	0.220	170.00	-9.0	21.2	399.6	130.0	127.5	49.0	
402.8	Elkhorn Slough/Skippers	2/2/84	BNC					-9.0	8.7	272.0	6.6	138.0	83.0	
402.8	Elkhorn Slough/Skippers	2/2/84	LNC					-9.0	5.7	142.0	3.6	123.0	64.0	
403.0	Elkhorn Slough/Highway 1 Bridge	5/29/80	TCM	7.633	2.533	0.147	113.33	-9.0	14.1	231.8	31.0	24.0	65.0	
403.0	Elkhorn Slough/Highway 1 Bridge	11/24/80	TCM	6.833	1.300	0.116	66.66	-9.0	10.9	156.1	21.0	140.0	100.0	
403.0	Elkhorn Slough/Highway 1 Bridge	1/15/85	TCM					-9.0	18.9	263.4	30.0	388.0	110.0	
403.0	Elkhorn Slough/Highway 1 Bridge	1/27/86	TCM					-9.0	8.1	116.3	11.0	130.0	27.0	
403.0	Elkhorn Slough/Highway 1 Bridge	1/29/87	TCM					-9.0	7.0	85.6	14.0	209.0	49.0	
403.0	Elkhorn Slough/Highway 1 Bridge	3/2/88	TCM					-9.0	6.7	56.0	13.0	247.0	-8.0	
403.0	Elkhorn Slough/Highway 1 Bridge	1/4/89	TCM					-9.0	14.6	110.3	13.0	70.8	25.0	
403.2	Moro Cojo	12/15/82	RBM					-9.0	-9.0	3036.0	-9.0	1500.0	-8.0	
403.2	Moro Cojo	1/4/89	TCM					-9.0	65.4	503.0	162.0	415.0	93.0	
403.5	Moss Landing/South Harbor	2/2/88	TCM	17.090	2.340	0.289	283.22	9568.4	-9.0	-9.0	-9.0	-9.0	-9.0	
403.5	Moss Landing/South Harbor	1/4/89	TCM	13.166	1.333	0.361	379.05	1900.0	-9.0	-9.0	-9.0	-9.0	-9.0	
403.6	Moro Cojo Slough	2/2/88	TCM					-9.0	22.9	326.5	41.0	212.0	83.0	
404.0	Sandholdt Bridge	2/24/82	RBM					-9.0	335.3	5301.0	180.0	770.0	320.0	
404.0	Sandholdt Bridge	11/17/82	RBM					-9.0	-9.0	7303.0	-9.0	1200.0	-9.0	
404.0	Sandholdt Bridge	12/15/82	TCM					-9.0	-9.0	1875.0	-9.0	530.0	-9.0	
404.0	Sandholdt Bridge	11/23/83	TCM					-9.0	185.2	3538.0	360.0	7200.0	340.0	
404.0	Sandholdt Bridge	1/16/85	TCM					-9.0	89.6	2212.0	120.0	1790.0	200.0	
404.0	Sandholdt Bridge	2/20/85	RBM					-9.0	100.0	2678.0	87.0	1450.0	220.0	
404.0	Sandholdt Bridge	2/20/85	RBM					-9.0	129.0	2950.0	98.0	1700.0	320.0	
404.0	Sandholdt Bridge	2/20/85	RBM					-9.0	127.0	3262.0	110.0	1920.0	300.0	
404.0	Sandholdt Bridge	9/18/85	RBM					-9.0	81.0	1126.0	54.0	120.0	340.0	
404.0	Sandholdt Bridge	11/18/85	RBM					-9.0	76.5	1270.0	76.0	1000.0	220.0	
404.0	Sandholdt Bridge	1/16/86	RBM					-9.0	98.4	1884.0	99.0	1580.0	300.0	
404.0	Sandholdt Bridge	1/16/86	TCM					-9.0	69.6	1412.0	78.0	1700.0	290.0	
404.0	Sandholdt Bridge	3/28/86	RBM					-9.0	164.3	3326.0	220.0	2250.0	480.0	
404.0	Sandholdt Bridge	11/24/86	RBM					-9.0	79.0	2160.0	70.0	857.3	170.0	

Type=Sample Type: RBM=Resident Mussel Tissue, TCM=Transplant Mussel Tissue
TFC [redacted] plant [redacted] ator [redacted]

Appendix 2

Ecological Surveys of Existing Drainage Ways

Qualitative survey of remnant biological communities along channels of the lower Salinas River watershed-Tembladera and Alisal drainage system.

Introduction

The lower Salinas Valley watershed is comprised of many agricultural drainage channels which have been cleared of most native plant communities and much of this area has been completely cleared of plants, leaving bare dirt. Small remnant plant communities are present in areas not actively cleared by the land owner or the Monterey County Water Resources Agency. Health of remnant communities relates directly to the amount of channel maintenance neglect the system has experienced, with the most natural communities receiving the most neglect. This qualitative survey lists the types of remnant communities present along this drainage, and identifies the biological importance they possess.

Plant communities occurred in a mosaic of predictable physical conditions influenced by drainage channel formation. Treatment of the plant communities by herbicide or physical removal contributed to the mosaic in a destructive but unpredictable fashion. Past and present land uses have contributed to the unpredictable nature of this plant community mosaic. The longer plant communities remained undisturbed the more stable and developed the community has become, e.g. large willow patches result from long periods of lack of disturbance due to channel maintenance. However, catastrophic disturbance have reversed years of willow grove development in some area by recent cutting or channel dredging.

Methods

Qualitative vegetation surveys were carried by Moss Landing Marine Lab botanists by visiting multiple locations along the Tembladera and Alisal slough system. Locations were chosen to ensure all habitat and community types were documented. Broader survey views were done from roadsides and other perspective points and with the use of aerial photographs and satellite imagery. The surveys included semiquantitative vegetation cover and relative abundance estimates. The relatively few plant species and even fewer dominants were readily identified in the field. Animals and their signs: tracks, scat and browsing evidence, were noted.

Results

Substrate structure, that is the shape of the drainage channel was important to vegetation patterns. Most ditches were simple cleared dirt channels and with bare sides. All ditches where unnaturally straight and the sides were uniformly smooth with steep slopes. Heights of the sides varied from little more than one foot to greater than ten feet. Cross sections of the channels varied but fell within two simple forms: deep and narrow, or broad and shallow. Rarely a third channel form was documented, one with an adjacent flood plain.

Vegetation patterns were related to the degree of herbicide treatment. Channel sides were often completely denuded. In other cases vegetation was present but dead. All plants were uniformly brown in color not normal for species at the end of their life cycle, indicating active use of herbicides. Herbicides appeared to be applied at various times of the year, without consideration of optimal timing for effective control of target species, i.e. just before seed set for annual species.

Native plant species

Native plant species represent persistent remnants of past pristine communities, and are considered desirable as wetland habitat. Native plant communities are indicative of stable conditions, undisturbed by human activities. Most native plants are perennials.

The two most desirable patterns of vegetation, observed in relatively undisturbed areas, were willow thickets and marsh thickets. Stream side willow thickets grew on low, flat areas adjacent to the channels, designated as "flood plain" above. Within these thickets, arroyo willow were over 20 feet in height. They formed dense foliage cover and provided physical complexity characteristic of riparian plant communities and valuable as faunal cover. Willow thickets provide a good historical model for pristine conditions along these waterways. Thickets are routinely destroyed by clearing channel sides to provide open areas. Many sites along the Tembladera and Alisal Rivers showed evidence of recent clearing of tree growth, including the thicket along the Old Lake Merritt outflow of the Tembladera Slough. This willow thicket (approximately 15 or 20 years old) was actively removed in mid October.

Most willow thickets were unconnected and existed as isolated islands of riparian habitat. These islands were usually formed in relation to land ownership boundaries.

The marsh thicket community grew out of the shallow channels. This community was comprised of dense emergent vegetation. Three species were dominant - tulles, cattails and burreed. All three typically grow in dense patches and may exceed 10 or 15 feet in height. They provide excellent faunal habitat. Cattails, particularly, are noted as aggressive colonists. Cattails were observed growing bank to bank in some shallow channels, whereas burreed and tulles distribution appeared patchy. (The original Spanish designation of the Tembladera slough was in reference to the large areas of tall, waving "grass", almost certainly tulle.) Less disturbed shallow channels also supported dense cover of marsh pennywort, water cress and duck weed, very low-growing and surface-floating plants.

The third substratum type, channel sides, received the most constant disturbance. Even where shallow channels supported dense vegetation, the sides were relatively barren. Routine herbicide applications were probably responsible. Steep slopes of smooth and somewhat impervious soil also make this substratum physically difficult to colonize.

One of the common native plants was fat hen. The species is found on disturbed sites as the earliest colonist and functions as a healer, initiating the process of community re-establishment. Knotweed, willow herb, nut sedge, nettles, golden rod and sedges also grew in this habitat.

Alien plant species

Alien, non-native, species, are generally considered to be undesirable weeds. They invade and grow on disturbed soils (with destroyed soil profiles) and usually remain chronically disturbed by human activities. Weeds are usually annuals or short-lived perennials able to succeed under unstable conditions.

Non-Point Source Pollution and Wetlands:

Impacts of Urban and Agricultural Nonpoint Source Pollution
on Sediments, Groundwater and Biota

Melanie L. Truan

A Review of the Literature

Produced for the Association of Monterey Bay Governments
through the University of California, Santa Cruz

12 March 1996

INTRODUCTION

"Originally, all pollution was of nonpoint (diffuse) nature. It became 'point' pollution when years ago people in urban and industrial areas collected urban runoff and wastewater and brought it, at a great expense, to one point for disposal" (paraphrase of a statement made by the urban environmental economist, M. Gaffney in 1988, as cited in Novotny and Olem 1994). Essentially, nonpoint pollution includes all those sources that are not point pollution, that is, sources that do not enter receiving water bodies at some identifiable single- or multiple-point location. Novotny and Olem (1994) categorize statutory nonpoint sources as:

- Return flow from irrigated agriculture;
- Other agricultural and silvicultural runoff and infiltration from sources other than confined, concentrated animal operations;
- Unconfined pastures and runoff from range land;
- Urban runoff from sewered communities with a population of less than 100,000, not causing a significant water quality problem;
- Urban runoff from unsewered areas;
- Runoff from small and/or scattered (less than 2 hectare) construction sites;
- Septic tank surfacing in areas of failing septic tank systems and leaching of septic tank effluents;
- Wet and dry atmospheric deposition over a water surface (including acid rainfall);
- Flow from abandoned mines (surface and underground), including inactive roads, tailings, and spoil piles;
- Activities on land that generate wastes and contaminants, such as:
  - Deforestation and logging
  - Wetland drainage and conversion
  - Channeling of streams, building of levees, dams, causeways and flow-diversion facilities on navigable waters
  - Construction and development of land
  - Interurban transportation
  - Military training, maneuvers, and exercises

Few alien plant species grew within willow thickets or in shallow channels. However, channel sides supported many alien weeds which often out-competed native species. This weed flora was continuous with the roadside weed "community" which grew out into field edges, roadsides and most other untilled but disturbed soils. Mustard, radish, poison hemlock, annual grasses, thistles were the most abundant and most dominating species of the roadside weed community. These species are invasive colonists and dominant competitors which must be controlled if native plant communities are to become established.

Another set of weed species was also observed, one which lived in wetter conditions than the roadside weeds community. Water grass, curly dock and prickly ox-tongue were the main constituents of this weed flora. They are also alien, invasive species. However, they provide beneficial wildlife value. In addition, they are not necessarily persistent dominants as the above mentioned species, but function more like fat hen: as an early colonists which gives way to successive native competitors.

Faunal assessment

Few animals were observed. Roadside weed communities are typically so disturbed as to provide only marginal and ephemeral wildlife habitat. Fish and aquatic insects are directly affected by water conditions and must be extremely hardy to tolerate the unpredictable chemical environment and low oxygen content of much of the water. Non-native mosquito fish and yellowfin gobies were observed in fresh water, and native sticklebacks in brackish areas. None were observed to be common. Snakes are air breathers and can tolerate, at least temporarily, polluted water where they were observed, but only rarely. Birds were most frequently observed in willows and cattail marshes. Most insects and amphibians observed occurred within the floating vegetation of the shallow channel plant communities.

Conclusions

Pristine conditions of these waterways provide the best model for restoration efforts. Remnants of pristine plant communities were best found in shallow water where alien weed species apparently cannot compete, and on adjacent flood plains where willows were able to dominate. The presence of appropriate native species along channel sides indicates the tenacity of native plant communities. The fact that native species were able to do so well in systems so profoundly altered physically, chemically and biologically is extremely encouraging. That is, restoration efforts would certainly be successful if the physical, chemical and biological forces acting against native plant communities were relaxed or redirected to encourage native plant establishment. Constant disturbance favors invasive species, almost without exception alien weeds. Conversely, absence of disturbance favors stable native plant communities.

Appendix 3

Non-point Source Pollution and Wetlands

Mass outdoor recreation

In addition, nonpoint source pollution (NPS) possesses some unique characteristics (Novotny and Olem 1994):

- NPS discharges enter the receiving surface waters in a diffuse manner at intermittent intervals, related mostly to the occurrence of meteorological events;
- Waste generation (pollution) arises over an extensive area of land and is in transit overland before it reaches surface waters or infiltrates into shallow aquifers;
- NPS is difficult or impossible to monitor at the point of origin;
- Unlike for the traditional point sources, where treatment is the most effective method of pollution control, abatement of NPS is focused on land and runoff management practices;
- Compliance monitoring is carried out on land rather than in water;
- Waste emissions and discharges cannot be measured in terms of effluent limitations;
- The extent of NPS emissions is related to certain uncontrollable climatic events, as well as geographic and geologic conditions, and may differ greatly from place to place and from year to year;
- The most important waste constituents from NPS subject to management and control are suspended solids, nutrients, and toxic compounds.

Runoff from urban and agricultural environments, the two major sources of NPS, will be discussed in this paper. Agricultural runoff consists of a "complex and highly variable mix of dissolved and suspended contaminants," whose composition is largely determined by "precipitation, topography, regional land use patterns, soil characteristics, fertilizer and pesticide application rates, and tillage practices" (van der Valk and Jolly 1992). Urban runoff is often highly polluted, especially the "first flush" stormwater following a prolonged dry spell. Urban stormwater constituents often consist of large quantities of sediment, phosphorus, nitrogen, septic effluents, organic compounds, refractory organics (pesticides and industrial chemicals), heavy metals, pathogens, petroleum hydrocarbons, and road deicing salts. These constituents can "all be found in quantities which can have adverse impacts to receiving waters" (Newton 1989).

TREATMENT OF NPS VIA WETLANDS

Mitsch and Gosselink, two of the foremost authorities in the field of wetland research, have described wetlands as "the kidneys of the landscape" (1993). This visceral, yet apt description refers to numerous observations of natural wetlands acting as sinks for certain chemicals. In fact, wetlands' role in enhancing water quality is often cited as one of the most important reasons for their protection. "The idea of applying domestic, industrial, and agricultural wastewaters, sludges, and even urban and rural runoff to wetlands to take advantage of this nutrient-sink capacity" is being increasingly explored (Mitsch and Gosselink 1993). Findings have suggested that wetlands for the processing of pollutants from wastewater are most effective in controlling organic matter, suspended sediments, and nutrients. Their effectiveness is less certain for trace metals and other toxic materials, not because these chemicals are not retained in the wetlands, but "because of concern that they might concentrate in wetland substrate and fauna" (Knight 1990 as cited in Mitsch and Gosselink 1993). This document presents current findings on the role of wetlands in processing agricultural and urban NPS, with special emphasis on the potential impacts of NPS contaminants on sediments, groundwater, and biological systems.

WETLAND FUNCTIONS AND VALUES

"Contaminated waters flowing through natural wetlands are cleansed by a combination of physical, chemical and biological activities and emerge as clean water" (Hammer 1992b). The ability of wetlands to perform this function is dependent upon four principal components: the water column, microbial populations, the substrate, and vegetation.

The physical purification activities of wetlands are primarily filtration and sedimentation, which act to remove sediment and attached contaminants. Chemical processes include partitioning and precipitation, adsorption of pollutants on plants, soil, and organic substrates, oxidation/reduction, volatilization, emulsification, hydrolysis, and photodegradation. Biological activities consist of the bacterial decomposition of complex compounds into simpler substances, the mechanisms involved in biotransformation, and the presence of plants and the processes afforded by their growth. Wetland plants are especially important, since they provide a substrate for filtration and bacterial activity, incorporate various compounds directly into their own biomass, and deliver oxygen to the water column and the root-soil interface. This additional delivery of oxygen increases the capacity of the system for aerobic bacterial decomposition and supports a wide variety of aquatic organisms, some of which may also directly or indirectly utilize additional pollutants Hammer 1992a).

Mitsch and Gosselink (1993) describe the attributes often exerting major influences on the chemicals flowing through wetlands:

- A reduction in water velocity, causing sediments and chemicals sorbed to sediments to drop out of the water column;
- A variety of anaerobic and aerobic processes in close proximity, promoting denitrification, chemical precipitation, and other reactions that remove chemicals from the water;
- A high rate of productivity that can lead to high rates of mineral uptake by vegetation, with the subsequent burial in sediments when the plants die;
- A diversity of decomposers and decomposition processes;
- A high amount of water-sediment contact and exchange, due to shallow water depths;
- The accumulation of organic peat in many wetlands, causing the permanent burial of chemicals.

These attributes, and the resulting processes of pollutant removal and transformation, are, in turn, affected by many controlling variables, including climate, flooding regime, soil type (organic vs. mineral), pH, vegetation type, and pollutant loading rate. It appears, however, that "the hydrologic regime and sediment levels in the wetland tend to be the dominant physical factors that control [pollutant removal] processes" (Bastian and Benforado 1988).

Natural vs. Created or Restored Wetlands

The majority of researchers surveyed feel that, although natural wetlands clearly possess considerable abilities to remove toxic constituents from wastewater, their use for this purpose should be discouraged. Few natural wetlands remain, and those that do are often crucial for wildlife. Most of these are already threatened by anthropogenic influences. Little is known about the long-term impact of discharging stormwater to natural systems. Such uses could have disastrous results.

However, creating wetlands, or restoring seriously degraded wetlands for stormwater management, "can have positive results" (Newton 1989). Created or restored wetlands, especially freshwater marshes, "can be adapted to a tremendous variety of soils, climatic conditions, and to wide fluctuations of water quality and hydrological conditions" (Novotny and Olem 1994).

Potential Problems with Treatment Wetlands

Despite the many features that wetlands possess for water purification, serious reservations exist regarding their use for nonpoint pollution control. Elder (1988) writes: "Like any other water purification alternative, the utilization of wetlands for treatment of contaminated water is not without difficulties, risks, and costs." These difficulties, risks, and costs have been explored within the confines of only a few limited projects, however, and often differ between projects. Hammer (1992b) warns that "the construction of wetlands is expensive and land-intensive, criteria are imprecise, full operational status is often delayed as the system stabilizes, and longevity of existing systems is unknown since most have been operational less than 20 years." Once a wetland is installed, some of the important managerial concerns include hydraulic changes, introduction of pathogens, bioaccumulation of toxics and biotransformation of non-toxic constituents to more toxic forms, synergistic effects of toxins, and overall long-term changes.

"Currently, there is a lack of criteria that can be used as the basis for determining whether a wetland will behave as a source, sink, or transformer for nutrients and pollutants" (Reddy and Gale 1994). Wetlands have widely varying abilities to remove sediments and pollutants from the water passing through them, but it is not yet known how to estimate their capacity to do so. Elder (1988) summarizes: "In very few, if any, situations does a wetland function as a true sink for nutrients and other contaminants. It is more likely to have a multiple role as a source, sink, and transformer, depending on the location, season, and innumerable environmental factors." Whether a wetland is a source or sink depends upon hydrology, the type of suspended solids, the density of the vegetation, and the morphology of the wetland (Kusler and Kentula 1989).

The roles of chemical, physical and biological characteristics, especially soil and hydrologic properties, in the functioning of the wetland ecotone all affect the fate of toxics in the wetland. In addition, the properties of the pollutants themselves also determine whether they will be retained, transformed, or exported. For example, some readily-oxidized organic compounds are quickly converted to carbon dioxide and water, while others, like some pesticides, are very stable and yield stable degradation products which are also toxic to the environment (Chan et al. 1982). Thus, wetlands should be sited correctly and not overloaded with contaminants. As wetland systems are reduced in size, or as volume and/or toxicity of pollutants increases, the ability of the system to accommodate and eliminate wastes can be impaired, and contaminants can bioconcentrate to levels harmful to wetland plants and animals (Catallo 1993; Willard and Hiller 1989).

Impacts on Wildlife

Knight (1992) writes that while "there is little evidence that [the direct and indirect environmental effects of toxins in wetlands receiving stormwater or agricultural drainage waters] represent a real limitation on the use of wetlands for flood control and water quality management . . . where inflow concentrations of toxins are a concern, or in specific environments where indirect toxic or lethal conditions may develop, wetland planning and design must seek to minimize wildlife impacts." Though the ultimate fate and subsequent effect of toxics on wetland flora and fauna are not well known, "wetlands that receive NPS loadings that will degrade the wetland should be protected by establishing upland buffer strips or other BMPs [Best Management Practices]" (Olson 1992).

Cumulative Impacts

It is important to consider all possible cumulative impacts to a treatment wetland. These include not only the accumulation of individual contaminants over time, but also the synergistic effects of combinations of low-level contaminants and their degradation products. Such a situation occurred at the Stillwater Wildlife Management Area in Nevada, where high salinity, a combination of contaminants found in irrigation return water, and atypical ratios of major ions (sulfate, magnesium, chloride, sodium, and calcium) "acted together to cause the observed toxicity; no single contaminant or water quality variable was responsible" (Lemly et al. 1993). Although the contaminants in this situation, like the one at Kesterson Wildlife Refuge in California's San Joaquin Valley, were introduced largely through subsurface irrigation drainwater, locally-derived contaminants inherent in soils and surrounding land uses can be concentrated in wetlands when fresh water sources are depleted. Lemly et al. Caution that "reduced freshwater inflows to wetlands, usually due to diversion of surface water for agricultural use, also substantially increases the potential for toxic conditions to develop in the arid climates where irrigated agriculture predominates." The cumulative impacts of surrounding land uses can also have profound impacts upon wetland water quality functions. While one agricultural field or one house may have minimal impact on a receiving water body, the cumulative effects of multiple fields or an entire housing development can be substantial.

PHYSICOCHEMICAL PROCESSES IN WETLANDS

Chesters (1986) summarizes the processes that can determine the fate of a chemical in a wetland system:

> A chemical can volatilize to the atmosphere, be adsorbed, be taken up by plants where it may or may not be degraded and hence might be returned to the soil-sediment in plant residue, be degraded by chemical, photochemical,

and/or microbiological processes, be leached to lower depths by water movement and diffusion, be transported by erosion/runoff, or be redeposited on land or reach surface water bodies. In many cases the fate of a particular chemical pollutant is determined by a number of processes.

Chemical Partitioning in Water

Partitioning is the "division of total pollutant mass between particulate and dissolved fractions in soil or sediment pore water" (Novotny and Olem 1994). A measure of this partitioning is the octanol/water partitioning coefficient (K_{ow}), which reflects the measure of solubility of a chemical in water. The mobility, and hence, the toxicity of metals and organics correlates directly to their solubility, which is related to the dissolved and ionic concentrations of the constituent in the water column, and in the pore water of the substrate.. Schnoor et al. (1987) provides more information on this subject, and describes processes involving toxic metals and organics. In general, the higher the solubility/dissolved fraction of a compound, the greater its bioavailability. However, highly soluble compounds tend to be lost more rapidly through leaching to surface- or ground-water, and therefore, tend not to persist or accumulate in soils, sediments, or living tissue.

Volatilization

Though not considered an official source of NPS, the import of volatile compounds from atmospheric deposition can have a substantial impact on wetlands. Conversely, the export of volatile substances from the aquatic environment can re-introduce chemicals like oils, chlorinated hydrocarbons, 2,4-D esters, and elemental mercury back into the terrestrial environment (Chan et al. 1982). Different compounds vary greatly in their volatility. For example, the highly toxic, low boiling point alkanes evaporate rapidly, while most large-molecular-weight petroleum hydrocarbons do not.

The presence of a film on the water's surface can inhibit volatilization by creating a non-polar barrier between water-borne polar solutes and the atmosphere. This film also acts to "scavenge and concentrate" nonpolar substances (fatty acids, esters, alcohols, lipids, hydrocarbons, and proteinaceous materials) from the water (Chan et al. 1982). In this way, surface films--and their chemical cousins, emulsions--can concentrate nitrogen, phosphorus, carbon, most heavy metals, chlorinated hydrocarbons and many other materials at levels greater than the surrounding water. For example, Chan et al. cite that "concentrations of zinc, cadmium, lead, and copper may reach 100 ppm in surface films, promoting reactions that may not otherwise occur and allowing ready entrance for the metals into the food web through surface-feeding fish, insects and other organisms." While the concentration and accumulation abilities of these films do pose a threat of possible contamination to the wetland food-web, they may also provide a means for removal of pollutants if the films themselves can be isolated and removed from the wetland.

Export of volatile compounds from wetlands can occur when a strong wind blows over open water, generating an aerosol foam from contaminated surface films. As the foam bubbles burst, droplets are ejected into the air. Water and other volatile substances quickly evaporate, leaving the aerosol residue (Chan et al. 1982).

Sedimentation and Adsorption

"Suspended sediments constitute the largest mass of pollutant loadings to surface waters" (U.S. EPA 1993a). Their sources are many, including: urban, agriculture, marinas, forestry runoff, and hydromodification. The nature of the flow pattern through wetlands is one of the most important mechanisms by which particulate pollutants are removed from the water column. The sheet flow of water through dense vegetation, and the highly meandering channels characteristic of mature wetlands are highly efficient in trapping and immobilizing sediments. Erwin (1989) describes some other processes that wetlands possess that affect contaminant trapping. The reduction of water velocity in streams causes dropout of suspended particulates. Anaerobic and aerobic processes drive denitrification and chemical precipitation. High primary productivity leads to high mineral uptake by vegetation and subsequent burial in sediments when plants die. A diversity of decomposers and decomposition processes allows processing of many different types of suspended contaminants. The intimate contact of water with sediments, due to shallow depths, leads to significant sediment-water exchange. Finally, the rapid accumulation of organic peat causes permanent burial of sediments.

Sedimentation of suspended solids is an especially important function of wetlands, since a substantial fraction of some toxic chemicals (organic compounds, petroleum and other hydrocarbons, halogenated hydrocarbons, and heavy metals (except Mn and Ni)) are adsorbed onto these solids (Tchobanoglous 1993; Chan et al. 1982). This sorption arises from a variety of different types of attractive forces (chemical, electrostatic, and physical) between dissolved molecules or ions, and the sorbing material. Clay and particulate organics provide the most suitable adsorption surfaces, with pH, temperature, and moisture content exerting the greatest influence on sorption dynamics (Novotny & Olem 1994). In addition, the fine-grained sediments typical of many wetlands can provide refuge or protection for microbes, invertebrate fauna, and plant roots, thus creating an environment conducive to the immobilization and/or degradation of toxic substances (Catallo 1993).

The high organic-matter production of wetlands "may be key" in disposing of low quantities of metals and organic chemicals, since they have a strong affinity for particulate and colloidal organic matter and sulfide ligants (Novotny and Olem 1994). These organic particulates are abundant in wetland systems due to the high primary productivity stimulated by nutrient inputs and recycling. Toxics complexed with organics are unavailable to aquatic biota, including plankton, plants, and animals, and can subsequently be filtered and/or settled out (Novotny and Olem 1994).

Therefore, deposition of sediment can result in removal of nutrients and toxins to an environment where either plant uptake of nutrients can occur, or where substances such as pesticides or aromatic hydrocarbons have time to undergo slow anaerobic decomposition processes. "In wetland systems where little reworking of sediments occurs, deposition of sediments can result in virtually permanent removal of most pollutants" (Boto and Patrick 1978). In fact, wetland recovery, following the introduction of hydrophobic contaminants, has been found to be a function mainly of chemical processes (weathering, sequestration), and the introduction of new, overlying sediments (Catallo 1993).

Oxidation and Reduction

When soils, either mineral or organic, are inundated with water, anaerobic conditions usually develop, due to a lowering of the rate at which oxygen can diffuse through the pore spaces. However, oxygen is not always completely depleted from the soil water of wetlands. There is usually a thin layer of oxidized soil, sometimes only a few millimeters thick, at the surface of the submerged soil. The extent of this layer is directly related to the rate of oxygen transport across the atmosphere-water interface, the numbers of oxygen-consuming organisms present, the amount of photosynthetic oxygen produced by algae within the water column, and the extent of surface mixing by convection currents and wind action. Even though the deeper layers of the wetland soils remain reduced, this thin oxidized layer is often very important in chemical transformations and nutrient cycling (Mitsch and Gosselink 1993).

The aerobic zone extends no further than a few millimeters from the site of oxygen release, and processes for the oxidation of carbonaceous and nitrogeneous materials occur here. Oxidation occurs when a chemical gives up one or more electrons, leaving the charged chemical (ion) in a more positive state. Reduction is the opposite of oxidation, occurring when a chemical gains one or more electrons. Oxidized ions such as $Fe^{(3+)}$, $Mn^{(4+)}$, NO_3^-, and $SO_4^{(2-)}$ are found in the aerobic microlayer, whereas the lower anaerobic soils are dominated by reduced forms such as ferrous and manganous salts, ammonia, and sulfides (Mitsch and Gosselink 1993).

As ammonia is oxidized to nitrate in the aerobic zone, the nitrate acts as terminal electron acceptor for denitrification through facultative aerobes in adjacent anoxic zones. In the absence of oxygen and nitrate, and as the redox potential (the measure of potential electron exchange) decreases, anaerobic degradation processes occur, using energy from $SO_4^{(2-)}$, $Mn^{(4+)}$, $Fe^{(3+)}$, and, ultimately, CO_2.

It is the presence of such diverse ecological environments that leads to the occupancy of a wide spectrum of microorganisms capable of degrading the variety of organic and inorganic compounds found in wastewaters. In reduced environments, sulfide precipitation of metals is the predominant process for inactivating toxic metals, while the organic particulate matter content of the substrate controls immobilization of nonionic organic compounds and organic mercury (Novotny and Olem 1994).

Reactions such as these usually do not occur in aerobic environments, where precipitation and other often less-favorable reactions with clays and organic matter dominate. Therefore, in wetlands, "the readily biodegradable portions of wastewaters are decomposed rapidly, while [more resistant] fractions may be incorporated into the organic sediment to be anaerobically degraded over an extended period, extending the overall retention time available for pollutant removal" (Wood 1990).

Hydrolysis

Hydrolysis appears to play a particularly important role in the breakdown of chlorinated alkanes and other toxic organic compounds, though the process may take months. Metals frequently act as catalysts. For example, cobalt and copper are known to catalyze the hydrolysis of glycine methyl ester. Other significant reactions include the acid-based catalyzed reactions of phthalate esters and phosphate esters to yield organic acids and alcohols which are biodegradable, the hydrolysis of the insecticides methoxychlor and dichlorodiphenyltrichloroethane (DDT) to dichlorodiphenylethylene (DDE), and the hydrolysis of 2,4-D esters to phenols (Chan et al. 1982).

Photochemical Reactions

Photochemical reactions (photolysis) operating in the thin surface film at the wetland surface can degrade, albeit slowly, some pesticides (malathion, parathion, 2,4-D esters, methoxychlor, and DDT) and aromatic hydrocarbons. Photolysis probably does not occur for the saturated chlorinated alkanes. EDTA is rapidly photodegraded in both acidic and basic waters. On the other hand, photolysis can produce rather than degrade toxic substances. "Ultraviolet irradiation of the hydrocarbons found in No. 2 fuel oil produces relatively soluble oxygenated compounds, including reactive peroxides, phenols, and carbonyl compounds" (Chan et al. 1982; Tchobanoglous 1993).

Export to Groundwater

Hydrologic exports from a wetland can occur both through surface water and groundwater, unless the wetland is an isolated basin that has no outflow (such as a northern ombrotrophic bog.) The tendency for a chemical to leach into groundwater depends on its degree of adsorption to soil particles. "Only soluble pollutants can penetrate into deeper soil zones and eventually pollute ground water" (Novotny and Olem 1994). The United States Environmental Protection Agency has developed an approach that incorporates the mechanisms of degradation and sorption into a procedure of assessment mobility of organic chemicals. Using this procedure, a mobility and degradation index (MDI) for ranking potential leaching of chemicals has been proposed by Mahmood and Sims (1986).

As discussed, the buffering capacity provided by abundant microbial populations, organic matter, weathered small-grain minerals (clays), a reducing chemical environment, plant uptake, and other factors inherent in a well-developed wetland substrate acts to intercept contaminants. The barrier presented by this biogeochemical gauntlet can be substantial, providing relatively effective protection for the groundwater regime (Novotny and Olem 1994).

There is, however, considerable debate over whether wetlands function primarily as receiving waters (discharge zones) or as sources for downstream and groundwater areas (recharge zones). The situation is complex and depends upon many factors, but current research suggests that many more wetlands are discharge areas than recharge areas (Carter and Novitzki 1988; Erwin 1989; Mitsch and Gosselink 1993). Most wetlands lie in depressions, where they receive surface- and ground-water inputs from local, intermediate, or regional flow systems.

Novotny and Olem (1994) suggest that the wetland/groundwater connection is poor since "the very existence of the wetland usually implies highly impervious substrate subsoils." In the few studies available, recharge occurred primarily around the edges of the wetland and was related to the edge:volume ratio (Mitsch and Gosselink 1993). Novotny and Olem also claim that "if a wetland is recharging, it acts a natural barrier preventing some mobile pollutants from entering the groundwater zones." Hammer

(1992a) agrees, claiming that most wetlands do not offer substantial recharge functions, but cautions that "a few natural wetlands may intersect groundwaters, such that subsurface waters flow horizontally through the wetland or, in a few instances, surface inflows may equal or exceed subsurface losses at least during a significant portion of the year." Newton (1989) underscores this, claiming that, during drier months, the same wetlands that normally act as receiving zones can act as discharge zones. O'Brien (1988) warns: ". . . the confining effect of wetlands, and the attendant groundwater circulation pattern, may concentrate iron and possibly other constituents in the aquifer under a wetland. In addition, well development may induce infiltration from peat deposits, leading to a change in redox potential and pH in an aquifer and a consequent change in water quality at the wellhead. Consequently, wetlands may exhibit considerable control over water quality in an aquifer."

Concerns over wetland-induced contamination of groundwater supplies have engendered certain precautions in the design of created or restored wetlands, and have encouraged the subsequent monitoring of their performance. In a project to treat landfill leachate in Escambia County, Florida, a liner was constructed of natural clay, excavated at the landfill. Subsequent tests revealed a conductivity of less than 1×10^{-10} cm/s for the clay liner; no infiltration of leachate to groundwater was detected (Dohms 1993). When wetlands are created with no special attention to enhancing substrate impermeability, however, leaching can occur. While investigating the low effluent volume of a constructed wetland cell, researchers at the Des Plaines River Wetlands Demonstration Project determined that "the low effluent discharge at the cell's outlet was a result of seepage through the bottom of the wetland" (Hey et al. 1994). However, since the wetland cell was exhibiting "high trapping efficiency," it may not have been exporting contaminants through the wetland substrate.

Even when substrate permeability is considered during the design phase, that permeability may be difficult to assess--let alone create--and may change in a restoration context. For example, "a sandy substrate may quickly become impermeable due to deposition of organics" (Kusler and Kentula 1989).

BIOLOGICAL PROCESSES AND INTERACTIONS

According to Catallo (1993), the impact of stormwater on wetland biota hinges on many factors, including:

- The identity of the pollutant mixture;
- The exposure time/duration/route;
- The environmental partitioning, speciation, and availability of contaminants under ambient conditions;
- The exposure concentrations and toxicities of individual components of the pollutant mixture;
- The life stages and physiological resilience of the exposed populations;
- The degree of interaction and connectance between populations;
- The presence of external forcing on the system (eg. tidal flushing, physical weathering processes, and natural stresses such as flooding or salt intrusion);
- The previous exposure of the system to particular pollutants or mixtures;
- The type and diversity of energy and functional linkages between populations;
- The various extrinsic factors, including experimental design, time of first sampling, duration and extent of sampling and stress introduced through field work.

As mentioned previously, the processes of partitioning and adsorption act to lower the bioavailability of toxic compounds. "A few materials (selenium) are selectively taken up by plants, but most are precipitated or complexed within the substrate" (Hammer 1992b). In contrast to lake and river sediments, wetland substrates are richer in particulate carbon and generally are anaerobic, both of which contribute to the lowering of many compounds' toxicity (Novotny and Olem 1994). This explains why some "potentially heavily contaminated sites with organic carbon sediments (such as some wetlands) can still support relatively viable biota (Novotny and Olem 1994). Nevertheless, Catallo (1993) states that the:

> . . . potential is high in wetlands for insidious or chronic degradation to manifest itself over the course of many years and at large spatial scales. Chemical coupling between wetlands and other systems may allow impacts to be manifested outside the wetland as well as *in situ*. As pollutant stress

> increases, the major observed ecological effects are decreased species diversity and biomass, changes in P:R budgets, altered trophodynamics, and altered biogeochemical functioning.

As contaminant loadings increase, the biotic community shifts from a diverse array of specialists, to "small numbers of generalists and opportunists at low biomass" (Catallo 1993). Generally, the sensitivity of different populations and the amount of time required for them to recover from acute contamination are inversely related to the biological complexity of the exposed organisms. "This relationship between structural simplicity and resilience may also apply to communities and ecosystems" (Catallo 1993).

Microbes

"Microbes play a major role in the transformation of substances critical to all life on earth" (USDA-SCS Engineering Field Handbook p13-14). In wetlands, populations of microbes in the substrate grade from anaerobic species in the deeper layers to aerobic species near the substrate-free water interface. Aerobic microbes also function in a thin, oxygen-rich zone, the rhizosphere, surrounding the roots of wetland vegetation. At the water surface, "mycorrhizal fungi facilitate nutrient uptake, reduce stress, enhance salt and contaminant tolerance, and enhance initial survival and growth of wetland vegetation" (USDA-SCS Engineering Field Handbook p13-14).

Typical of most ecological processes, several major factors affect the efficiency of chemical biodegradation: pH, temperature, water, clay and organic carbon content of soil, oxygen and nutrient availability, nature of microbial populations and their acclimation to the chemical(s), and the concentration of the chemical(s) (Novotny and Olem 1994). While aerobic microorganisms can facilitate the rapid decomposition of many organic and inorganic biodegradable compounds, facultative or strict anaerobes, using alternate electron acceptors, "may be capable of decomposing cellulose and cyclic organics, reducing nitrates to nitrogen gas, and converting DDT to DDE" (Novotny and Olem 1994).

The microbial processes affecting nutrient transformations, trace and toxic metal mobility and bioavailability, and the degradation of pesticides, petroleum hydrocarbons and industrial organics are very different in wetland soils compared with upland soils. In liquid and gas phases, organic and metallic compounds with low water solubility and vapor pressure tend to adsorb to particles or be entrained in colloidal systems, micelles, microlayers and aggregates. Once deposited, prevailing sediment chemistry (redox conditions, pH, nutrient levels, organic matter type and content, particle-size distribution, and mineralogy) and microbiological conditions can alter the speciation, chemical properties (water solubility, exchangeability, volatility) and toxicity of many organic and inorganic contaminants.

Although changes in microbial communities and populations are observed in highly polluted areas, their interpretation is complicated by factors including: high levels of natural spatiotemporal variability; time-dependent development or recruitment of resistant species; and method limitations, including interlaboratory comparison and quality assurance. In general, microbial systems exposed to organic and metallic pollutants have been shown to undergo "at least temporary decreases in species diversity; dominance of adapted, generalist, or resistant populations; changes in metabolic function; and in some cases, biomass stimulation in populations of indigenous pollutant metabolizers" (Catallo 1993). Microbial systems do exhibit substantial resilience, however, perhaps due to factors such as protected niche, (interior of aggregates, deep sediment horizons) biochemical adaptation, and protective mechanisms (encystation). In addition, microbial systems and their process outputs tend to recover quickly to previous conditions when exposure to pollutants is eliminated (Catallo 1993).

Wetland Flora

While the primary pollutant removal mechanisms in wetlands consist of physical, chemical, and microbial interactions, aquatic plants also provide valuable water quality functions. A dense surface vegetation promotes a uniform distribution of water across the wetland, slowing its flow, filtering solids, and increasing contact time with the substrate. In addition, "plant uptake of pollutants, particularly from the sediments, frees more exchange sites for further pollutant interaction and accumulation" (Chan et al. 1982). In addition, certain hydrophytes appear to accumulate substantial concentrations of heavy metals.

Most researchers agree, however, that the direct role of aquatic plants in wetlands is to provide surfaces for bacterial growth, to filter solids from the water column, to translocate oxygen from the air to the anaerobic root zone, and to improve soil permeability. This latter function is acheived when roots and rhizomes loosen the substrata, increasing percolation by forming pores of tubular shape, which upon decay leave horizontally interconnected channels. "These will to stabilize the hydraulic conductivity of the rhizosphere at a level equivalent to coarse sand within 2-5 years, regardless of the initial porosity of the soil" (Wood 1990; Novotny and Olem 1994; Chan et al. 1982; Bastian and Benforado p87-89).

The lack of oxygen in saturated soils prevents plants from carrying out normal aerobic root respiration and strongly affects the availability of plant nutrients and toxic materials in the soil. As a result, plants that grow in anaerobic soils generally have a number of specific adaptations to this environment (Mitsch and Gosselink 1993). Hydrophytes possess specialized xylem vessels, called aerenchyma, which transport oxygen to the root zone, or rhizosphere. Some researchers theorize that this aerobic zone may constitute a buffer between the roots and certain toxic substances present in anaerobic substrates. McKee and McKevlin (1993) state that "through aerenchyma oxygen transport to roots, nutrients can be obtained oxidatively by roots while minimizing exposure to toxic forms or concentrations of metals and sulfur." Hammer (1992a) claims that "the juxtaposition of a thin-film aerobic region surrounded by largely anaerobic substrates is important in nitrogen, carbon, hydrogen, sulfur, and metal cycling [and] detoxifies potentially hazardous substances and modifies nutrients and trace organics." In addition, this "protective space" (Seidel 1976) may allow benign bacteria to survive during high loadings of heavy metals or other toxic elements, and to subsequently recolonize the area (Chan et al. 1982). On the other hand, Conlin and Crowder (as cited in McKee and McKevlin) claim that "rhizosphere oxidation may actually exacerbate metal toxicity problems by creating a steep concentration gradient between roots and surrounding reduced soil." In addition, some plant species are more effective at aerating their root zones than others. For example, "*Typha latifolia* will produce aerobic zones and considerable biomass in wetland hydrosoils, while *Scirpus cyperinus* (bulrush) and *Zizania aquatica* (wild rice) should permit formation of anaerobic zones" (Rodgers and Dunn 1992).

Although little is known about the processing capabilities of wetland plant systems receiving continuous pollution, studies suggest that "vegetation systems can function well even in severely polluted areas" (Chan et al. 1982). Species tolerant of waterlogging are generally capable of differential, selective uptake and translocation of nutrients. Thus, they can maximize the uptake of essential nutrients, such as nitrogen, phosphorus, potassium, and calcium, while limiting the incorporation of potentially toxic nutrients such as iron and manganese. In addition, transport of materials, especially toxic forms, from the root to the shoot is often more limited than actual uptake by the roots. Hydrophytes also adapt to toxic substrates by producing shallow root systems that are not in contact with the more highly-toxic, reduced material lower in the soil profile (McKee and McKevlin 1993).

It appears that different plant species can be employed for different bioremediation functions. Willard et al. (1989) cited the use of reed canary grass (*Phalaris spp.*) and red top (*Agrostis stolonifera*) for erosion control, woody vegetation for wildlife habitat, and hardy species such as catttail (*Typha spp.*), bulrushes (*Scirpus spp.*), and reed grass (*Phragmites communis*) for wastewater treatment. Accordingly, individual plant species also vary in their water treatment capacities. "The degree of uptake, bioconcentration, and tissue disposition of organic and metallic contaminants in freshwater marsh plants usually is species-specific and varies with different chemicals, metals, and substrate physicochemical conditions" (Catallo 1993).

Hydroponic studies of freshwater wetland plants in the presence of dissolved zinc, cadmium, nickel, lead, and chromium (0.5 and 1.0 ppm), showed growth inhibition in *Scirpus validus* and mortality of *Cyperus esculentus* during a six-week experiment. While metals were assimilated in the roots of both plants, only *C. esculentus* translocated zinc, cadmium, and nickel to aerial parts (Catallo 1993). Researchers also found that floating plants, such as duckweed (*Lemna spp.*), bioconcentrated arsenic and selenium, as well as a range of trace and heavy metals (including mercury) from sediments or fly ash suspended in the water column (Catallo 1993).

In another study, a freshwater marsh was established on dredge spoils containing a range of toxic metals (zinc, nickel, chromium, lead, cadmium) and chlorinated hydrocarbons (Kepone, DDT, DDE, DDD, lindane, chlordane, heptachlor epoxide, endrin, dieldrin, Kelthane [dichofol], toxaphene, and PCB cogeners in Aroclor 1260). Of this contaminated suite, only nickel and the structurally analogous compounds DDE and Kelthane were assimilated by one or more of the subject plant species (*Peltandra virginica, Echinochloa sp., and Typha sp.*) above levels observed in two natural marsh controls (Catallo 1993).

Despite the apparent lack of substantial plant bioaccumulation of toxics reported in these studies, "recent research has documented biological transfer and amplification of toxic material by certain wetland plant species" (Kusler and Kentula 1989). Catallo claims that "trophic transfer of pollutants assimilated by floating or submerged aquatic vegetation can proceed both by direct consumption of live plant tissues and through detrital systems" (1993). He emphasizes, however, that the "trophic transfer of many trace metals and chlorinated hydrocarbons in emergent wetland plants [may be] mediated primarily by detrital systems rather than by direct consumption of aerial plant material by insects, mammals, birds, or fish." Nevertheless, some researchers suspect that the use of wetlands in stormwater treatment may increase toxic loading associated with runoff and result in the ultimate biological amplification of toxic materials (Catallo 1993; Kusler and Kentula 1989).

Wetland Fauna

Invertebrates

Besides plants, invertebrates are perhaps the best indicators of environmental health. Macroinvertebrates are especially good indicators because they are sensitive to environmental stress, are relatively long-lived, and reside at almost every trophic level. Macroinvertebrates can also serve as early indicators of contaminant problems, since many are detrital feeders or scavengers. In addition, invertebrate taxa diversity and abundance respond rapidly to environmental stresses and sampling methods are simple and easily conducted (Hammer 1992a).

Meiofauna are sediment invertebrates that range in size from 63-500 micrometers. These organisms and their associated microbial systems occupy niches that are frequently exposed to dissolved and adsorbed pollutants. "The turbative and grazing activities of meiofauna are positively correlated with microbial productivity, changes in redox potential or reworked sediment, changes in bulk sediment properties, and vertical fluxes of nutrients, metals and pollutants" (Catallo 1993). The limited number of studies available suggest that "meiofauna may experience increased body burdens of contaminants, biomass and community structure alterations, morbidity and death of sensitive species, and alteration of biologically mediated physical and chemical properties of the sediment" when exposed to toxic chemicals (Catallo 1993). They are also usually the first to recover from large chemical or petroleum spills that destroy all benthic organisms, possibly through opportunistic dominance of species resistant to specific pollutant mixtures (Catallo 1993).

Hydrophobic pollutants, including DDT, PCBs, and zinc, nickel, copper, and cadmium, have been shown to accumulate in marine and freshwater benthic infauna, and may be accumulated by deposit and suspension feeders, carnivores, and detritivores (Catallo 1993). Adsorption of hydrophobic contaminants onto nematode cuticles and assimilation of trace metals by nematodes have also been reported, indicating a route of "toxic chemical transfer from sediments to detrital organisms, followed by transfer to higher food chains" (Catallo 1993).

Fish

Numerous toxicological studies exist on the effects of pollutants in fish. Most of these have been made in the relatively unbuffered environments of lakes, streams, and estuaries, not in wetlands where various processes help to remove toxics from the water column. However, wetland studies are increasing. From 1980 to 1986, Winger et al. (1988) collected fish from 20 National Wildlife Refuges in the southeastern U.S.--composed of wetlands and associated aquatic resources--to test for residues of organochlorine chemicals and elemental contaminants. "In fish from five refuges, mean residue concentrations of total organochlorine chemicals (primarily DDT and toxaphene) exceeded 2.00 micrograms/gram (wet weight)--levels high enough to pose a threat to fish-eating wildlife." They found that most refuges in the Southeast reflected contamination from agricultural chemicals, but only five of the 20 were seriously contaminated.

It would seem logical that the greatest effects of pollutants on fish in wetlands would be on those species most closely associated with substrates, or those that directly consume other organisms which are accumulating toxins. Hammer (1992a) reports that "in contrast to other vertebrates, fish (especially bottom feeders) are exposed to contaminants in the sediments and analysis may provide early warning of accumulation and bioconcentration."

Birds

In a study conducted on the impacts of agricultural chemical-induced changes in prairie pothole habitats, Grue et al. (1988) reported that "agricultural chemicals that enter prairie-pothole wetlands may impact adult and juvenile waterfowl directly through lethal and sublethal effects, or indirectly by altering vegetative cover or food abundance." They claimed that "of the 16 most widely-used insecticides in North Dakota in 1984 ($>10^4$ ac treated), 9 ha[d] been implicated in wildlife mortality elsewhere, and of these, 4 (carbofuran, chlorpyrifos, methyl and ethyl parathion) ha[d] been associated with the death of waterfowl." Furthermore, their findings suggested that "the food habits and foraging behaviors of juvenile and adult waterfowl may increase their exposure to agricultural chemicals above that of some wetland wildlife and make them particularly vulnerable to pesticide-induced reductions in aquatic invertebrates and plants."

Few studies exist to document the detrimental effects of pollutants on bird species that utilize wetlands designed primarily for water treatment. Dr. Donald Hey, director of the Des Plaines River Wetlands Demonstration Project, reported no observed detrimental effects on the bird species frequenting their wetlands, even though numbers of species of migratory waterfowl were up 500% and numbers of individuals had increased by 4500% since 1985 (pers. comm.). Harriet Hill, of the California Environmental Protection Agency, in the course of investigating current findings regarding wildlife impacts of constructed wetlands, found little to no evidence of harm to wildlife from treatment wetlands (pers. comm.).

While this apparent lack of negative findings is encouraging, it may be that these systems have not been studied long enough to display the deleterious effects of chronic loading of environmental contaminants. In addition, since these systems are highly interconnected, seemingly insignificant factors may have far-reaching effects. For example, study is currently being focused on anaerobic bacteria (*Clostridium botulinum)* and wetland waterfowl infected with deadly avian botulism (Adler 1996).

AGRICULTURAL NONPOINT SOURCE POLLUTION

Agricultural practices adjacent to wetlands can have dramatic influence on wetland performance. Soil eroded from cropland as sediment usually contains a higher percentage of fine particles than the parent soil on the cropland. This selective erosion can increase overall pollutant delivery since small soil particles have a much greater adsorptive capacity for pollutants than larger particles. As a result, eroding sediments generally contain higher concentrations of phosphorus, nitrogen, and pesticides than the parent soil (EPA 1/1993).

In addition to heavy sediment, nutrient, and pesticide loadings, inputs to restored wetlands in agricultural landscapes are characterized by irregular and high volume hydraulic loadings. DeLaney (1995) claims that "these frequently shock the wetland's physical, chemical and biological systems, and thus, alternative functions like wildlife habitat and recreation should not be considered as serious secondary objectives when NPS control is the wetland's primary objective." If ancillary objectives are necessary for the wetland's establishment, then the use of Best Management Practices (BMPs), such as conservation tillage and buffer strips, must be explored. Alternatively, a series of small wetlands may be installed, in which the primary wetlands perform most of the water treatment functions and the most terminal, downstream wetlands provide areas for recreation and habitat for wildlife (DeLaney 1995).

If such conservation design guidelines are followed, wetlands can provide "superior performance and flexibility" in controlling pollutants from agricultural nonpoint sources (Novotny and Olem 1994). Many constraints on the restoration of wetlands in agricultural landscapes will serve to dictate their installation. Most significant is cost and land availability. Wetlands will usually have few water-control features; little, if any, basin excavation; no seeding or planting, and will tend to be small. Initially, their vegetative composition, primary production, secondary production, and nutrient cycles will not resemble those of natural wetlands. "Because the primary source of water will be agricultural runoff, often containing high amounts of nutrients, sediments, and pesticides, these wetlands may never become similar in composition, structure, or function to natural wetlands" (van der Valk and Jolly 1992).

PESTICIDES

Wetlands designed for agricultural NPS can be expected to receive substantial loadings of pesticides: algicides, fungicides, herbicides, and insecticides. Clark et al. (1993) state that:

> Although pesticide use on any single field, crop or infected forest may be intermittent, stream flow integrates multiple contaminant sources within a drainage area. Larger streams thus have potential pesticide inputs over extended periods. Because larger stream systems commonly drain land areas of diverse uses, areas within the watershed not receiving pesticides provide dilution potential for contaminated runoff. Pesticides reaching coastal areas from upland sources have had maximal opportunities for physical and biological degradation as well as sorption onto or into particulate matter or sediments.

Recent data, summarized in the National Pesticide Survey, a statistically designed survey of pesticides and nitrate in drinking water wells of the United States, shows that 46 pesticides have been detected in groundwater from 26 states. The herbicides atrazine, aldicarb, and alachlor were most commonly found (Baker 1992).

Pesticides can be transported to receiving waters either in dissolved form or attached to sediment (Rodgers and Dunn 1993). The fraction of the pesticide mass sorbed to particulates and the dissolved or aqueous fraction that is transported depends on the character of the pesticide and the sorbents in the agricultural soil (Rodgers and Dunn (1993). The physical-chemical characteristics of some agricultural pesticides significant to water pollution potential are given in Table 1.

Except for unusual circumstances, such as severe storm events soon after application, pesticide losses from cropland are on the order of 1-5%, and concentrations in runoff and receiving waters are much lower, in the microgram per liter range (Menzel 1983). The timing and magnitude of runoff events after pesticide application is crucial in determining pesticide loss, with impacts being most severe from events large enough to mobilize pesticides, but small enough to avoid excessive dilution.

	Insecticides			
Characteristics	Organochlorines	Organophosphates	Carbamates	Herbicides
Adsorption	H	M	L-M	L-M
Water Solubility	L-M	M-H	M-H	M-H
Degradation	S-M	M-R	R	M-R
Route to Water	Sp[a]	MSP[b]	Md[c]	MD
Persistence in water	M-H	L-H	L	L-M

Source: Modified from Edwards 1977, taken from Menzel 1983
Note: L=low; M=moderate; H=high; S=slow; R=rapid
Sp[a] = soil particles
MSP[b] = mainly soil particles
MD [c] = mainly dissolved

Table 1. Physical-Chemical Characteristics of Agricultural Pesticides Significant to Water Pollution Potential.

Dissolved pesticides may be leached to groundwater supplies (EPA 1/1993). Due to their high degree of solubility, herbicides present the greatest threat to groundwater supplies (Fisk 1989). While, as mentioned previously, stormwater runoff from croplands does introduce a *substantial* amount of pesticides into aqueous environments, the majority of organic chemicals reported in groundwater appear to originate from improper chemical waste disposal (Schaller and Bailey 1983).

Adsorption and Degradation of Pesticides

In typical surface soils and sediments, the adsorption of nonpolar synthetic organics is usually controlled to a large extent by large molecular weight humic materials, rather than clay content, with hydrous oxides of iron and manganese assisting in the immobilization process. The chemical nature, and the amount of organic matter and hydrous oxides in wetlands are affected by the redox environment (Gambrell and Patrick 1988). The presence of dissolved organic carbon (DOC) in interstitial water in the form of dissolved humic and fulvic materials can bind or form complexes with xenobiotic compounds, thus reducing compound bioavailability. Word et al. (1987) observed a significant difference between interstitial water LC50 values for DDT-spiked sediment whenever the source of organic carbon (OC) varied. Mineral OC forms, such as coal may not affect chemical sorption and bioavailability in the same way as DOC and particulate OC forms. Surface area, as well as molecular and physical structure of different forms of OC in sediment may influence bioavailability. Interestingly, sediments with similar OC content do not similarly affect bioavailability of neutral organic compounds, other factors must affect sorption and bioavailability (Suedel et al. 1993).

Different pesticides vary in their solubility and mobility in aqueous environments. The strongly adsorbed organochlorine insecticides are least mobile, followed by organophosphorus insecticides which are slightly more soluble. The water soluble acidic herbicides are the most mobile. Other pesticides, including triazines, atrazines, phenyl ureas, and carbamates, have an intermediate degree of mobility. On the other hand, the organic cations, diquat and paraquat, are held strongly by clay and often are adsorbed irreversibly (Novotny and Olem 1994). The affinity for pesticide adsorption onto sediments has been documented, and a review by Pionke and Chesters (1973) discusses transport of pesticides by sediments and the rate of decomposition of various pesticides.

The dominant degradation mechanism for pesticides in anaerobic environments is by microbes--although 2-chloro-s-triazines are chemically hydrolyzed. In general, organochlorines are the most resistant to microbial attack. Partial degradation of DDT results in the formation of TDE (DDD) and DDE, both stable in soils and sediments with about the same toxicity as the parent compound. Other organochlorines (heptachlor, lindane, and endrin) degrade more readily to compounds of lower toxicity and reduced insecticidal activity, so trapping of the sediment on which they are adsorbed will result in efficient removal.

Compared to organochlorines, most currently used pesticides are fairly biodegradable. The pyrethroid insecticides are not particularly water-soluble (10-20 ppb) and readily adsorb to plants and soil, where they are generally subject to hydrolysis, photolysis, and biotransformation (Rodgers and Dunn 1992). The newer vinyl phosphate insecticides (phosphamidon, chlorfenvinphos, mevinphos) have half-lives in soils ranging from 1-30 weeks, with chlorfenvinphos being the most resistant to decay (Novotny and Olem 1994). Crosson (1983) cautions that "the shift from organochlorines to organophosphates was to change the environmental damages of insecticides from those that are subtle, diffused, and long-term to those that are sharp, localized, and short-term."

Many types of pesticides are degraded quickly (Pionke and Chesters 1973). However, some pesticides, like the herbicide alachlor, show differential rates of decomposition under aerobic and anaerobic conditions. Pothuluri et al. (1990) report that anaerobic decomposition of alachlor is much slower than aerobic breakdown, depending upon the availability of alternative carbon sources and secondary electron acceptors. In addition, they suggest that "alternating exposure to aerobic and anaerobic environments may stimulate metabolism of some pesticides."

Many synthetic organic compounds, including DDT and toxaphene, actually degrade more rapidly under anaerobic conditions. In a lab study of the degradation rates of approximately twenty synthetic organic chemicals under varying redox conditions, all but two, permethrin and Kepone, were influenced by soil or sediment redox conditions (Gambrell and Patrick 1988).

If substances are not readily decomposed by chemical or microbiological processes, ultimate removal may be achieved by burial. If the wetland has a reasonably high accretion rate, and if phytotransformation or some other activity that resuspends the deposited materials does not occur, the chemicals will remain in the bottom sediments indefinitely (DeLaney 1995; Boto and Patrick 1978). Though limited data exists on enrichment ratios for tightly-adsorbed pesticides, they are probably similar to that for organic matter (Novotny and Olem 1994).

Pesticide Transfer and Transformation Prediction Model

Rodgers and Dunn, (1992) in studying pesticide transfer and transformation rates in wetlands, claim that "pesticide removal processes can be adequately described by simple exponential decay." The underlying assumptions to this model are that pesticide transfer and transformation in wetlands follow first-order or pseudo-first-order kinetics, and transport of a pesticide in a wetland can be reasonably approximated by a single number, the Pesticide's Residence Time (PRT). The PRT in a given wetland will be determined by the character of that wetland, such as plant density, porosity, wetland dimensions, water flow, and pesticide retention factors such as sorption, etc., as well as runoff events that influence pesticide inputs to the wetland. The PRT is also a function of the intrinsic chemical character of the pesticide. These assumptions will probably permit accurate predictions for most situations until more data are available to indicate more complicated or appropriate approaches. When these pesticide removal rates are compared to known environmental toxicology data, the mitigation capabilities of wetlands for reducing the effects of pesticides on downstream aquatic systems can be predicted.

Bioaccumulation of Pesticides and Impact on Biota

Aqueous concentrations of pesticides tend to diminish over time at any one site within a habitat, and tend also to diminish with increasing distance from the source of the toxic material, unless there is a continuous input (Clark et al 1993). Although more soluble, less strongly adsorbed compounds may readily enter waterways dissolved in runoff, they also tend to be more rapidly degraded and diluted, which usually diminishes their potential for bioaccumulation. More insoluble pesticides, bound to organic or inorganic matter, tend to be more persistent and are subject to greater physical and biological concern. In general, the pesticides in greatest agricultural use today, primarily organophosphate insecticides and herbicides of many formulations, pose reduced threats to aquatic organisms, being less persistent and having lower acute toxicity levels.

There are few biological generalities relative to acute pesticide toxicity levels. The effects are species-specific. Body size, age, sex, and overall health of an organism, as well as various physiological stresses, can be influential. In most cases, however, herbicides and carbamate insecticides are rapidly metabolized and excreted by aquatic animals and are much less toxic than other organic pesticides (Menzel 1983). Assessing potential impacts to wetland biota must take into account the potential route and duration of exposure to the pesticide. Factors such as chemical toxicity, potential exposure concentrations, environmental persistence, and frequency of use are also important (Clark et al. 1993). For coastal wetlands, potential for exposure increases in regions with longer growing seasons, in areas supporting crops that require more persistent pesticides or more repeated applications, and with large percentages of nearby acreage dedicated to agriculture (Clark et al. 1993).

Dissolved Pesticides

Exposures to relatively constant pesticide inputs can result in lasting changes in community structure and function, with only tolerant species prevailing. Exposures to pulse inputs associated with runoff from storm events or direct inputs following pesticide applications offer greater dynamic responses among the biota, and fluxes of biotic viability. These dynamic effects can be imposed on natural, seasonal cycles of animal and plant movement in these systems, making exposure-response assessments difficult to quantify. Finally, the net effects of repeated pulse inputs over a growing season, and over several growing seasons, define the total impact of pesticides on wetlands (Clark et al. 1993).

Exposure effects on aquatic species depends to a great extent on whether the biota are pelagic, epibenthic, or infaunal, and whether the species or life stages are mobile or nonmotile forms. Pelagic organisms that are immobile or relatively nonmotile and become entrained in a contaminated water mass moving through a wetland may have exposure durations dependent upon the rate of mixing and dispersion of the contaminated water with other site water. Mobile species, pelagic or epibenthic, may actively avoid contamination. Immobile species may experience pulses of pesticides as contaminated water and particles move through a system. Those species adapted to burrowing, reducing metabolism during stress, or some other means of minimizing exposure to external media may actively reduce their short-term exposures to the relatively high concentrations of pesticides pulsed through the system. Animals that spend only a portion of their life cycles within wetlands and use them as nursery areas, feeding grounds, or migratory paths may be exposed to pesticides if visits coincide with inputs. Residual pesticides trapped in sediments or persisting as body burdens in resident species as a result of prior exposures, may find their way to species that spend only portions of their lives in or near wetlands (Clark et al. 1993)

Adsorbed Pesticides

In contrast to dissolved pesticides, contact with particulate-associated pesticides is much more difficult to assess. Mixing and transport still are major factors in the rate and extent to which water-column organisms encounter contaminant particles, but the disposition and long-term fate of the particles and their associated pesticides are complex. Particles within the size range of filter-feeding biota can become a source of contaminant exposures. Larger particles that settle out can contaminate epibenthic habitats. Sediment-incorporated particles can expose infaunal species. Anaerobic sediments create a major sink for pesticide-contaminated particles, serving as a contaminant source during times of erosion or resuspension, such as major storm events (Clark et al. 1993).

Flora

Many terrestrial and aquatic plants are capable of adsorbing and translocating pesticides, followed by possible detoxification to a less active compound. In addition to physical and chemical removal of biocides, plants and the highly varied microbial populations of a wetland will metabolize many organic biocides (Chan et al.). However, the extent of this detoxification may be minimal (Novotny and Olem 1994).

Accumulation in plant tissue affects considerations for the ultimate use or disposal of plant material. Uptake of organochlorine insecticides is dependent upon plant lipid content and contact surface area available for absorption (Chan et al. 1982). This can affect secondary consumers that can concentrate these biocides and experience toxic effects. "Data from experimental ponds suggest that herbicide levels of a fraction of a milligram per liter can produce subtle effects on plant production at the lowest trophic levels in aquatic ecosystems, leading to indirect effects on populations of higher organisms" (Wauchope 1994).

Among emergent aquatic plants, the water lily (*Nymphaea alba*) has been found to accumulate hexachlorocyclohexane (HCCH) and DDT to 10-12 times ambient water levels. *Nymphaea odorata* and *Paspalum distichum* (jointgrass) were found to absorb the insecticide mevinphos at the rate of 7 ppm/day. In contrast, the submerged rush, *Juncus repens*, showed no propensity for mevinphos removal (ABAG 1982).

Submerged plants, such as pondweed, grow in direct contact with water-borne pesticides. At low biocide concentrations, submerged plants appear to be able to accumulate and metabolize biocides without showing toxic effects. *Potamogeton pectinatus* has been shown to accumulate DDT and HCCH at average levels of 3.8 and 0.94 mg/kg dry weight. DDT uptake comparisons have also been performed on different pondweed species. Removal of the pesticides dichlobenil, diphenamid, and amitrole were measured on *Elodea canadensis, Potamogeton diversifolius, and Myriophyllum spicatum.* All plants were affected by dichlobenil concentrations of 0.17 mg/l and took up small amounts of diphenamid. Only *Elodea* accumulated amitrole. *Myriophyllum brasiliense* degraded diphenamid to a relatively nontoxic monomethyl derivative. *M. brasiliense* was shown to absorb the herbicide simazine through the roots (Chan et al. 1982).

Fauna

The highly water-soluble pesticides--aldrin/dieldrin, endrin, toxaphene, and benzidene--can be extremely harmful to aquatic organisms, causing either acute or chronic effects (California Coastal Comm.Guidance Manual 1995). As a group, all the fungicides for which data are available are highly toxic to fishes, but less toxic to birds or mammals (Fisk 1989). Certain pesticides have been found to inhibit bone development in juvenile fish, or to affect reproduction by inducing abortion. A few of the herbicides are highly toxic (paraquat, 2,4,5-T, and 2,4-D) but most are moderately or only slightly toxic (Fisk 1989; Crosson 1983). Atrazine, which accounts for almost 25% of all herbicide use, has low toxicity to humans. There is some evidence, however, that it may be transformed metabolically by plants to form a substance which is mutagenic (Plewa and Gentile 1976 as cited in Crosson 1983). Certain herbicides have also been found to destroy food sources for higher-order organisms, to reduce the natural vegetation needed for protective cover, and to reduce egg-laying in aquatic species (California Coastal Commission Guidance Manual 1995).

Many synthetic organic chemicals such as pesticides have the tendency to persist in the aquatic environment and bioaccumulate in the food chain, to be passed onto higher-order animals and eventually to humans (CCC Guidance Manual 1995). Organochlorines such as DDT and dioxins biomagnify in the wetland food chain because of their affinity for fats (Knight 1992). Overall, insecticides pose the greatest threat in terms of acute toxicity. Of those for which data are available, 21 have been shown to be extremely toxic to fishes, 21 extremely toxic to birds, and 27 extremely toxic to mammals. Some of these insecticides have been shown to be more acutely toxic than compounds such as DDT, aldrin, and endrin, which were banned or restricted at least in part because of their respective toxicities (Fisk 1989).

The National Contaminant Biomonitoring Program has determined that since the use of some of these organochlorines has been banned or controlled, concentrations in fish have generally declined, especially DDT, PCBs, toxaphene, chlordane, and endrin (Baker 1992). Nevertheless, as discussed above, these highly-persistent contaminants continue to be flushed into aquatic systems from existing soil concentrations during runoff events. A case study on the processes affecting the fates of DDT, its degradation product, DDE, and toxaphene residues in fish indicated that the "source of contaminants in the fish was the frequent transport of fresh residues into the lake from surface runoff and erosion, rather than accumulation and recycling of residues between the lake mud and surface waters" (Gambrell and Patrick 1988). Once these residues became associated with the anaerobic lake sediments, degradation was believed to be sufficiently rapid to degrade most within a few weeks or months. Nevertheless, Rappaport et al. (1984), as cited in Baker (1992), "postulated that continuing input of DDT to the United States occurs by atmospheric transport from Central America, where it is still used."

Effects of Chronic Pesticide Exposure

Although a compound may be only moderately or slightly toxic in terms of its LD50--the amount of compound that proves lethal to 50% of a test population--this does not necessarily mean that it could not pose threats to wildlife. At concentrations lower than the LD50, a smaller portion of the population could suffer mortality, or effects less severe, including chronic effects (Fisk 1989). Menzel (1983) cites reports of chronic effects, including reduced growth, reproductive failure, lowered disease resistance, impaired osmoregulation, altered metabolism, and abnormal behavior in laboratory studies. Table 2 presents some guidelines for predicting toxicity and bioaccumulation potential of agricultural pesticides in aquatic animals.

	Insecticides			
Effect	Organochlorines	Organophosphates	Carbamates	Herbicides
Toxic action	Neurotoxic, axonic, gangli-onic	Neurotoxic, cholinesterase inhibiting	Neurotoxic, cholinesterase and acetyl-choline in-hibiting	Variable
Bioaccumulation	M-H	L-M	L	L-M
Acute toxicity				
Microcrustaceans	M-H	M-H	M	L-M
Macroinvertebrates	M-H	M-H	M-H	L-M
Fish	M-H	M	M	L-M

Source: Modified from Edwards 1977, taken from Menzel 1983

Note: L=low; M=moderate; H=high

Table 2. Toxicity and Bioaccumulation Potential of Agricultural Pesticides in Aquatic Animals

Synergistic Effects

Recently, researchers have begun to study the synergistic effects of various contaminants on biological systems. A recent National Public Radio broadcast (Living on Earth, 11/10/95) presented some findings regarding the effects of mixtures of chemicals on living organisms. Dr. Warren Porter, from the University of Wisconsin at Madison, reported that a mixture of low levels of three pesticides, including a close relative of atrazine, administered to rats, resulted in "an elevation of thyroid levels . . . a suppression of learning abilities and spatial discrimination capabilities . . . a suppression in the speed of learning . . . [and] changes in certain nerve transmitters." Dr. Ana Soto of Tufts University reported that experiments on mixtures of commonly used chemicals (pesticides, plasticizers, food preservatives) on human cells have shown that "minute quantities" of these chemicals, if found singly, will not be a problem, but together "can produce an effect." More research is needed to better characterize the potential for long-term effects of multiple chemical inputs and to discern potential impacts of repeated or continual low-level exposures on the growth and reproduction of resident species; on the growth and survival of nonresident biota that utilize wetlands as feeding grounds, nursery areas, or migratory habitats; and on the complex functional interactions associated with energy and materials processing (Clark et al. 1993).

Case Study - Agricultural NPS

Long Lake, St. John Valley, Maine

This constructed wetland-pond system has, in series, a sedimentation basin, a grass filter strip, a constructed wetland, and a retention pond which discharges to a final vegetated polishing filter. Runoff, collected and diverted from cropland, first enters the sedimentation basin where the water is detained to allow larger particles to settle and reduce the hydraulic impact on downstream components. Once the basin fills, overflow enters a level lip spreader--a trench filled with crushed rock--whose purpose is to evenly distribute the sediment basin discharge across the width of the filter strip, reducing channelization and erosion. Drainage tiles were placed under the filter strip to promote infiltration of the runoff, which is then discharged to the wetland. After flowing over the grass filter strip, the remaining runoff enters the wetland. Here, the wetland vegetation further impedes flow, settling more particles. Nutrients are adsorbed at the soil-water interface and are also taken up by plants and microbes. Finally, the water enters the retention pond. Permanently flooded, this pond gives greater retention times to settle smaller particles. The wetland-pond is stocked with small algaevorous fish and freshwater mussels. The diverse biological community creates a well-developed food chain which helps to remove nutrients from the water column. The water level in the wetland-pond is controlled by a standpipe which discharges into a vegetated swale that drains to the lake.

The sequence of each component was carefully considered to address the unique problems associated with agricultural runoff, with the system sized to treat and contain storm events of varying frequency and magnitude. The sediment basin was placed first to protect downstream components from sediment overload. The grass filter strip was placed ahead of the wetland-pond to serve as an early indicator of the adverse impact of pesticides, since it was felt that the health of the grass in the filter strip would be a good indicator of overall pesticide load. Since 1989, the system has functioned well, requiring minimum maintenance. Most summer storms are contained within the sedimentation basin alone, which provides about half of the total contaminant removal (Higgins et al. 1993).

Design for Agricultural NPS Reduction

"The most efficient approach to controlling agriculture-related NPS pollution--and the most acceptable to landowners--employs a combination of accepted BMPs for waste handling and erosion control along with constructed and natural or restored wetland systems in a hierarchical system" (Hammer 1992b). Novotny and Olem agree, observing that the conversion of polluting agricultural lands to buffer strips or high slope woodland, combined with the creation or restoration of riparian wetlands, "could provide an improved water-pollution control benefit." Additional information regarding design guidelines for constructed wetlands will be given at the end of this paper.

URBAN NONPOINT SOURCE POLLUTION

The National Urban Runoff Project (NURP) concluded that:

- Urban runoff contains high concentrations of toxic metals; "priority pollutants" (toxic, mostly organic chemicals) were also detected in significant quantities;
- Urban runoff is contaminated by coliform and pathogenic bacteria;
- Urban runoff carries high quantities of sediment.

Though urban runoff has been identified as a major source of toxics, including toxic metals and petroleum hydrocarbons, very little is known about the long-term effects of these substances on the biota of receiving bodies of water (Novotny and Olem 1994). Therefore, the use of wetlands for controlling trace metals and other toxic materials, contrary to that for controlling organic matter, suspended sediments, and nutrients, is less certain due to the concern that they might concentrate in wetland substrates and fauna (Knight 1990).

Refractory Organics

Refractory organics consist of man-made chemicals that resist chemical decomposition or bacterial digestion. Included in this broad class are: pesticides, herbicides, household and industrial cleaners and solvents, photofinishing chemicals, dry cleaning fluids, and petroleum hydrocarbons. They may enter wetlands by direct or indirect routes. The immediate source of most industrial chemicals to urban runoff is atmospheric fallout (adsorbed to dust particles) derived from uncaptured or uncontrolled industrial and motor vehicle emissions. Most pesticides and herbicides in urban runoff are washed from landscaping, the majority adsorbed to sediments (Newton 1989).

Marsh plants have been determined to be capable of removing a variety of refractory chemicals from waters. It appears that both microbial activity and uptake by higher plants can function effectively to remove at least some complex organic chemicals. Table 3 provides data on the disappearance of various organics in systems containing *Scirpus* lacustris.

Compound	Concentration mg/l	Days to Extinction
Phenol	100	15-29
p-Cresol	30	15-52
Pyrogallol	100	15-52
Pyridine	400	7-9
Quinoline	20	7-9
Aniline	20	15-52
p-Chlorophenol	10	14-52

Table 3. Disappearance of Various Organics in Systems Containing *Scirpus lacustris* (Seidel 1966, taken from Kadlec and Kadlec 1978)

The principal impact of refractory chemicals on wetland biota is acute toxicity. In urban streams, there have been occasional fish kills and other acute toxicity incidents resulting from illegal or accidental discharge of significant volumes of refractory organics and waste chemicals into storm drains and roadside ditches. Low-level contamination by refractory chemicals also exists in receiving bodies such as estuaries, and thus, may be a problem in wetlands as well (Kadlec and Kadlec 1978; Newton 1989).

Petroleum Hydrocarbons

These chemicals are derived primarily from urban sources and marinas, and consist of motor vehicle fuels, lubricating oils and greases, tars, and asphalts (CCC Guidance Manual 1995; Newton 1989). Sources of petroleum hydrocarbons in urban runoff include engine blow-by (now largely eliminated by smog control devices), partially burned fuels in motor vehicle exhaust, general leakage from engines and drive lines, improper disposal of waste crankcase oil in gutters and storm drains, and accidental spillage. Most oil pollution is caused by low levels of chronic leakage.

Depending on their molecular weight and substituents, these hydrocarbons can either evaporate, adsorb to sediments, dissolve in water, or float as a film (Newton 1989). The low molecular weight hydrocarbons, both aliphatic and aromatic, are quite volatile and usually evaporate before runoff occurs.

The aliphatic hydrocarbons are a diverse group of open-chain compounds which may be halogenated. Many of these are priority pollutants of environmental concern: carbon tetrachloride, dichlorobromomethane, chloroethane, dichloromethane, dichloropropane, vinyl chloride, chloroform, bromoform, tetrachloroethane, trichloroethane, methyl chloride, and methyl bromide. These volatile compounds have little or no affinity for adsorption, and thus are highly available to aquatic organisms.

The aromatic hydrocarbons can be monocyclic (benzene, toluene) or polyaromatic (anthracene, benzo(a)anthracene, benzofluoranthene, chrysene, fluoranthene, napthalene, pyrene). Many polyaromatic hydrocarbons (PAHs) have been found to be carcinogenic. Monocyclics are moderately soluble and moderately volatile, so larger scale sorption on soils and sediments doesn't occur, while the PAHs have a larger affinity for adsorption (Novotny and Olem 1994).

Structural properties also affect the capacity for adsorption. Emulsified oils can adsorb to particles, but physical agglomeration inhibits adsorption. Chan et al. (1982) report that the tendency for a petroleum hydrocarbon (and many other organic compounds as well) to adsorb:

- Increases with molecular weight as a homologous series is ascended, unless the molecule is so large as to be filtered out by small carbon pores;
- Decreases with the compound's polarity, and hence, solubility;
- Decreases with the position of substitution of hydroxy and amino groups on benzoic acids in the order: ortho, para, and meta.

In addition, the character of the particle/oil/water system affects the degree of sorption:

- Adsorption is greater with decreasing size of the sorbent particles; up to the point where the small pore size causes interference;
- Adsorption increases with increasing content of organic matter in the particles;

- Little adsorption occurs on inorganic particles such as clays if very low organic compound concentrations exist in the water.

Adsorbed hydrocarbons settle to the bottom, where microbial degradation can occur. Soil and sediment microorganisms are capable of degrading PAHs and some other petroleum hydrocarbons. Highly branched aliphatic hydrocarbons biodegrade slowly, if at all. Analyses of marsh muds and organisms collected after a one-time oil spill showed some uptake of hydrocarbon material, but a general persistence of heavier materials (Chan et al. 1982). In another case, microbial processes were probably responsible for the dissolution of hydrocarbons from chronic petroleum input to a shallow water marsh (Kadlec and Kadlec 1978). Photolysis can also degrade some PAHs (anthracene).

Some aquatic organisms seem relatively unaffected by hydrocarbons, while others have a low threshold for toxicity. Filter feeders, such as shellfish, can become contaminated by hydrocarbons, making them unfit for human consumption. Furthermore, bacterial species, such as those known to feed upon and digest hydrocarbons in marine habitats, are unknown in freshwater systems (Newton 1989).

Heavy Metals

Urban NPS typically contains substantial amounts of heavy metals. A typical assay of metals found in urban runoff in Bellevue, Washington (Newton 1989) contained arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn). Other metals found in 50% or fewer of the samples included nickel (Ni), antimony (Sb), beryllium (Be), mercury (Hg), selenium (Se), silver (Ag), and thallium (Tl). Of these, however, only copper and zinc were found dissolved in the water to any significant degree. The other metals occurred as adsorbed substances on sediment particles. Typical sources for heavy metals include: brake linings and tires, lead from motor vehicle emissions (declining), and industrial wastewater discharges. Most deposition occurs from atmospheric fallout, where the ultimate source is uncontrolled or unregulated industrial emissions (Newton 1989).

While "elevated total concentrations of metals do not necessarily result in problem releases to water or excessive plant uptake," the chemical forms of these metals and the processes affecting their transformations are important in assessing risk (Gambrell 1994). Metals in the environment can exist in various forms, (listed in order of decreasing solubility/availability):

- Water-soluble metals (free ions, inorganic complexes, organic complexes)
- Exchangeable metals
- Metals precipitated as inorganic compounds
- Metals complexed with large molecular-weight humic materials
- Metals adsorbed or occluded to precipitated hydrous oxides
- Metals precipitated as insoluble sulfide
- Metals bound within the crystalline lattice structure of primary minerals

Metals in their free ionic state are the most toxic to organisms. Therefore, toxicity and bioavailability can be reduced by the presence of compounds that will react with the metal ion and cause its precipitation or adsorption to solids. The colloidal and ionic compounds that form a complex with the metal ion include organic acids and humic substances, dissolved sulfides, chloride, and hydroxyl (OH^-) ions. The adsorbing and complexing compounds for toxic metals include:

Particulates: sulfides, iron and manganese oxyhydrates, particulate organic matter, and clays;

Dissolved: sulfides, humic compounds, organic acids, chloride ion (Cl^-), and hydroxyl ion (OH^-)

Dissolved metal-organic (ligand) complexes may also be adsorbed by particulates, such as iron and manganese oxyhydrates. Some dissolved organic compounds, such as detergents, may reduce the adsorptivity of metals, while chlorides may enhance adsorptivity. Of all the preceding mechanisms, iron and manganese oxyhydrates provide the strongest adsorption sites, followed by particulate organics and clays (Novotny and Olem 1994).

"The heavy metal content of wastewater apppears to be reduced as it passes through wetlands and at least initially appears to accumulate in sediments and vegetation" (Bastian and Benforado 1988). An investigation into the action of reducing sediments revealed that all of the zinc, almost all of the copper, and most of the nickel and cobalt (Co) were bound to humic-type materials (Nissenbaum and Swaine 1976).

Metals Processes in Wetland Soils

In metal-contaminated wetland soils, the chief processes of concern are:

- Release of metals to surface water from sediments and flooded soils;
- Metal uptake by wetland plants;
- Metal accumulation by benthic and wetland animals;
- Runoff losses;
- Leaching losses.

There are a number of physical and chemical properties of soils that affect metal mobilization-immobilization processes. Physical properties include soil texture (proportion of sand, silt, and clay), as well as the type of clay minerals. Fine-textured soils and sediment containing an appreciable amount of organic matter tend to accumulate metal complexes, while more coarse-textured soils may allow leaching. Chemical properties include redox potential, pH, organic matter content, ionic strength, presence of competing cations, salinity, and the presence of some inorganic chemical components such as carbonates and sulfides (Gambrell 1994).

Under reducing conditions, metals precipitated as inorganic compounds generally include metal oxides, hydroxides, and carbonates. The stability of these inorganic metal compounds is controlled primarily by pH. Metals tend to be immobilized at neutral to alkaline levels, but can be mobilized if the pH becomes moderately to strongly acidic, as in oxidation. Metals complexed with large molecular weight organics, however, tend to be relatively unaffected by changes in pH. Research suggests that these complexes remain effectively immobilized unless subjected to long-term oxidizing conditions or significant loss of total organic matter (Gambrell 1994).

In contrast, oxides of iron (Fe), and perhaps manganese (Mn) and aluminum (Al), tend to become unstable under reduced conditions. "In wetland transition zones and/or where seasonal changes occur in soil flooding, these hydrous oxides may form and dissolve as a function of changing hydrology, consequently holding and releasing metals within the soil" (Gambrell 1994). Fortunately, for surface soils and sediment materials (top few millimeters or so) iron oxyhydroxides may be effective in controlling metal retention during flooding and drainage cycles (Gambrell 1994).

Several studies suggest that "sulfur may play a very significant role in the process of the immobilization and detoxification of metals" (Novotny and Olem 1994). Sulfur enters the wetland through the atmosphere (acid rainfall), through runoff, or through seawater diffusing into strongly reducing interior pore spaces. The anaerobic conditions typical of wetland soils and substrates favor the reduction of sulfate to sulfide, accomplished by heterotrophic bacteria that use sulfate as an electron acceptor instead of oxygen. Sulfide is toxic to plants, but the anion readily reacts with many equally toxic heavy metal cations, (Fe, Cu, Ag, Zn, Hg, Ni, As, and Se) forming insoluble complexes which then precipitate out of solution (McKee and McKevlin 1993; USDA-SCS Engin. Field Handbook 1992; Novotny and Olem 1994). The processes that form these metal sulfide complexes can, however, be reversed by aerobic conditions and a resulting decrease in pH. In contrast with metal-humic material associations, where the change in metal immobilization may be modest, transition from strongly reduced to oxidizing conditions for extended periods will result in loss of all sulfide and the subsequent release of metals (Gambrell 1994). "Up to 87% flushing of [sulfuric] materials have been reported under aerobic conditions" (Novotny and Olem 1994). Under acidic or aerobic conditions, "other properties of the substrate, such as organic matter and clays, will control toxic metal activity," (Novotny and Olem 1994) though "perhaps a little less effectively" (Gambrell 1994).

Partial decomposition of organic matter produces a variety of low molecular weight acids, which act to chelate metals. These acids lower the pH, promoting the dissolution of metals from solids, making them available for chelation. Chelation is important to the mobility of aluminum, cadmium, calcium (Ca), chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. For example, microbial exudates readily chelate copper, lowering its normally extreme toxicity (Chan et al. 1982). As mentioned previously, naturally-occurring, large molecular weight organic compounds like humic and fulvic acids are also important ligands. There are also ligands in most wastewaters and stormwaters, derived from industrial, domestic, and agricultural chemicals. For example, ethylenediaminetetraacetic acid (EDTA) is added to fertilizer to permit uptake of iron by plants. Through runoff transport, EDTA, and other ligands, can affect the distribution of metals in wetlands, and their subsequent uptake by vegetation.

Mercury, arsenic, and a few other less-important metals, undergo biological methylation in anaerobic sediments. These organic-complexed compounds are far more toxic than their inorganic counterparts, since they are strongly polar and behave similarly to free metal cations. Anaerobic sediments have been found to release ten times more toxic arsenite $As^{(3+)}$ than aerobic sediment layers. The toxic effects of conversion of inorganic mercury by bacteria residing in sediments into organic methyl or dimethyl compounds, and the subsequent ingestion by fish and later, humans, were tragically illustrated at Minamata Bay and Niagara Falls (Novotny and Olem 1994).

Heavy Metals and Groundwater

The processes that tend to immobilize metals in wetland soils should act to retain metals released into wetlands from point and nonpoint sources. ". . . assuming favorable hydrology and reasonable loading rates. . . . leaching of metals would be a minor problem" (Gambrell 1994). At relatively slow-flow rates, the adsorptive surfaces of clays and other fine-textured soils, and humic materials, "should effectively scavenge and retain trace and toxic metals. If sedimentation is occurring in the wetland, the gradual burying of bound metals is going to place them in an environment where immobilization processes become more effective" (Gambrell 1994).

It is critical, however, to acknowledge the processes attendant to the dewatering of a wetland site that has received loadings of toxic metals, and is sequestering them in the sediments. The aforementioned oxidation processes and loss of organic material engendered by the drying, dredging, and/or upland placement of contaminated sediments can result in substantial leaching of dissolved, and highly-toxic, metals to surface- and ground-water sources.

Flora

As opposed to the majority of findings regarding the effects of NPS toxics on wetlands-- where a limited number of studies find most researchers in general agreement-- opinions as to the extent of interaction between metals and wetland vegetation contrast sharply. It may be that this lack of consensus is a direct result of the relatively greater number of studies in this area than in other areas of wetland ecology. If so, this should be considered in interpretion of the results of a minimal number of experiments. A small number of studies can produce limited, often one-sided results. We know very little about wetland ecology, and past experience has shown that the dangers of jumping to conclusions are great.

Levine and Willard (1989) report that studies on metals uptake by plants suggest that "soil conditions typical of marshes, such as moisture saturation, high organic matter content, near-neutral pH, and low oxygen concentrations, cause metals to be in insoluble forms, [thus restricting] the transfer of these metals into plant tissue." On the other hand, an Army Corps of Engineers report, *Wetlands and Water Quality* (1986), based on a study by Ragsdale and Thorhaug (1980), claims that there is "some evidence that wetland plants are remobilizing metals from the sediments ("mining") and transporting them to adjacent waters." This study showed generally higher concentrations of heavy metals in plant tissue at the end of the growing season when plants were senescing and forming litter, and presumably being exported from the wetland.

Knight (1992) reports that arsenic, cadmium, chromium, nickel and zinc are quickly concentrated in soils and plants compared with water concentrations, primarily through direct adsorption and absorption. Plant tissues have been shown to bioconcentrate these metals from 100 to 1000 times their levels in water. Nevertheless, Knight claims that concentrations are not magnified through the food chain. "These metals essentially reach saturation levels in tissue based on water concentrations, and additional uptake is matched by tissue metal losses, resulting in a relatively constant body burden. As long as source control or pretreatment prevents consistently high concentrations in the wetland influent, levels toxic to biota are unlikely to occur." In contrast, microbially-methylated forms of mercury and lead bioaccumulate in plants and also become concentrated through food-chain biomagnification. These metal-organic complexes have an affinity for lipids and so are accumulated in tissues during the organism's lifetime. However, as with other metals, excretion and release mechanisms do exist for methylated mercury, lead, and organochlorines (Knight 1992).

In a study by Lunz (cited in Catallo 1993) of 40 freshwater plant species growing in a freshwater marsh established on dredge spoils, 11 were rated "medium" or "high" for uptake of one or more trace metals (Zn, Cu, Pb, Ni, Cd, Cr, or Hg), including species of the genera *Alternanthera, Justica, Lemna, Myriophyllum, Phragmites, Potamogeton, Eichornia, Sagittaria, Spirodela, Typha, and Zizaniopsis.*

Chan et al. (1982) report that, "when applied in excess, trace nutrients can accumulate and pose potential long-term hazards to plant growth and secondary consumers. Copper, zinc, nickel, and cadmium are metals that can accumulate in soils and lead to phytotoxicity. Cadmium, and to a lesser extent, copper, can become hazards at high concentrations to secondary consumers of plants enriched with these elements."

Gallagher and Kibby (1980), as cited in *Wetlands and Water Quality,* compared the uptake of trace metals by plants growing in a natural marsh compared to a wetland established on contaminated dredge spoils. They found that concentrations of cadmium, lead, and zinc were no higher in plants grown on dredged than in natural soils. Copper, however, was significantly more concentrated in three of the four species sampled. However, most of the plants were dead after 18 months, suggesting that chronic metal concentrations were too toxic for normal growth.

In most systems, physicochemical interactions in sediments operate as the primary pollutant sequestering/removal mechanisms. Biochemical interactions exist as secondary mechanisms for incorporation of trace elements into a system. Thus, biochemical processes can provide additional capacity for pollutant removal, but "generally, only 4-5% of the nutrient loading . . . is incorporated into plant or animal tissue. A few materials (eg. Se) are selectively taken up by plants, but most are precipitated or complexed within the substrate" (Hammer 1992b). Heavy metal ions can adsorb onto particulates or form complexes with inorganic phosphorus, and settle in sediment layers. Concentrations of these pollutants are highest in the top few centimeters of sediment, and, unless immobilized into nonsoluble forms, are available to rooted emergent vegetation, particularly those with shallow roots or creeping rhizomes near the sediment surface.

Pollutants in ionic form can be actively taken up by plants and accumulated in concentrations in excess of their environment. Environmental conditions, such as increased light, temperature, and carbohydrate energy sources, generally promote ion transport, whereas anaerobic conditions may inhibit absorption of specific ions. Plant cell membranes are not permeable to free ions of elements. Ions can only be transported across the cell membrane into the plasma through carriers (probably enzymes that have active sites that are specific for particular types of ions). Heavy metal availability to plants is dependent upon solubility and is, like that of the refractory chemicals, directly related to redox potential and inversely related to pH. In a study of *Spartina alterniflora* and *S. cynosuroides* roots suspended in an aqueous soil slurry amended with labeled cadmium and maintained under controlled pH and redox potential, the plants exhibited greater uptake of the cadmium under oxidizing conditions (Gambrell and Patrick 1988).

Certain plants accumulate dissolved materials, including trace contaminants, that are not required for plant growth or function. This nonspecificity is a function of general nutrient uptake processes where some minerals, such as strontium (Sr) and calcium, are interchangeable ions in plant metabolism. In other cases, the accumulation of heavy metals, without apparent toxic effect, may be due to the presence of chelating compounds which combine with the metal ions to form harmless complexes. For example, pondweed (*Potamogeton pectinatus)* takes up lead readily, incorporating it into cell walls, which renders the lead inactive and harmless to the plant (Chan et al. 1982).

Trace contaminants can be taken up and preferentially stored in different plant parts. In pondweed (*Potamogeton pectinatus*), zinc accumulates in the stems and leaves, most other heavy metals tend to concentrate in the roots and rhizomes. Tolerance of a heavy metal varies for any single plant species, and tolerance of one metal does not necessarily indicate tolerance for another (Chan et al. 1982).

"The rate of accretion and degree of burial will be important factors in determining the loading which the systems can endure without damaging the all-important vegetation" (Boto and Patrick 1978). Various researchers have found that for cadmium, a dosage rate of $15 mg/m^2/yr$ results in 80% retention by sediments, while a larger dosage of 43 $mg/m^2/yr$ results in retention of only 45%, illustrating the importance of loading rate (Boto and Patrick 1978).

The detrital zone also aids in the uptake and immobilization of contaminants. Dead, but not yet decomposed cordgrass litter in a saltwater marsh was found to be able to adsorb heavy metals directly from the water. Decomposing litter releases humic acids which act as metal chelators, effectively immobilizing heavy metals. The organic litter layer in these grass stands appeared to act as a sink, accumulating more heavy metals than the living plant mass (Chan et al. 1982).

Submerged aquatic vegetation, generally shallow-rooted, absorb metals readily through both roots and shoots. The heavy metal contents of these plants are proportional to environmental concentrations. "*Elodea* can cycle elements rapidly through an aquatic system, taking up heavy metals from soil and water, retaining a portion within the plant, and releasing 60-70% of the initial amount absorbed back into the water. Although removal potentials have not been documented in terms of kg/ha, various studies have shown that *Elodea* can be more effective than other submerged plants and more effective than emergents, such as the common reed, in removing copper, manganese, and chromium from water" (Chan et al. 1983).

Floating aquatic vegetation, such as duckweed (*Lemna spp.*), generally absorb more minerals directly from the water than plants that are rooted in sediment. "The high productivity of duckweed can lead to active uptake and accumulation of trace metals beyond ambient water concentrations" (Chan et al. 1982). *Lemna minor* displayed biomagnification factors of 20,000 to 100,000 times ambient water concentrations for cobalt, copper, nickel, and titanium; and 300,000 to 660,000 times ambient water concentrations for iron, manganese, and aluminum. "It is possible that the continual decay process, associated with plants that have high productivity, releases these trace elements continuously to the upper waste layers, so that they are recycled to new plant growth" (Chan et al. 1982).

In general, emergent aquatic plants have lower heavy metal content than floating or submerged plants (Chan et al. 1982). However, some emergent macrophytes may accumulate some metals in relatively high concentrations. For example, iron levels as high as 5000 mg/kg, and manganese concentrations up to 4100 mg/kg, were found in cattail (*Typha spp.*) leaves and stems grown in experimental cells that were heavily loaded with acid mine drainage (Hammer 1992b). These high concentrations did not appear to have short term detrimental effects on growth and vitality, however. A study by Lan et al. (1990) also supported the ability of *Typha* to assimilate contaminants (mostly in the root portion) without apparent harm to the plants themselves. Mine wastewater passing through "luxuriant" stands of cattails in the purification pond was found to have total reductions in suspended solids (99%), biological oxygen demand (55%), lead (95%), and zinc (80%). An ecological survey of this site indicated that there were "several species of algae and fish flourishing in the pond, usually with higher density in areas containing lower metal concentrations in the water." As a result of these impressive statistics, many constructed wastewater wetlands have incorporated extensive plantings of *Typha* into their designs. There are drawbacks to this practice, however. *Typha* often dominate less aggressive species, producing extensive monocultures. While this may be effective for highly-loaded wastewater processing systems, it is detrimental to the establishment of a complex community structure, capable of supporting a diversity of biological systems and processes.

Various other aquatic macrophytes show varying degrees and patterns of metals uptake. Mercury absorption by bulrushes (*Scirpus cyperinus*) through submerged shoots increased with increasing aquatic mercuric chloride concentrations. *S. lacustris* showed significant removal potentials for zinc, as did *Carex stricta* for iron in a wastewater pond (Chan et al. 1982). In a study of 15 sites around the country, compared under continuously flooded vs. upland regimes, cadmium uptake by yellow nutsedge (*Cyperus esculentus* L.) was greater under upland conditions for all but one site (Simmers et al. 1981, as cited in Gambrell 1994). This study also investigated the uptake of copper, nickel, lead, and zinc from plants growing on contaminated dredge materials. They found that the plants growing under continuously flooded conditions did not accumulate any more metals than plants growing in nearby natural marshes. Plants growing on the contaminated materials in upland conditions, however, did accumulate substantial amounts of the metals.

Reeds may be useful in removing significant amounts of copper and iron, and moderate amounts of cobalt (Co) and molybdenum (Mo). Except for late fall and winter, when reed metabolism is geared towards seed production, root concentrations of metals are always greater than leaf or stem concentrations (Chan et al. 1982). In the water willow (*Justicia americana*), maximum uptake of heavy metals in aboveground tissues occurs prior to the production of peak aboveground biomass, offering significant removal potentials for zinc (2.6-5.8 kg/ha), manganese (1.3-2.5 kg/ha), and copper (0.30-0.80 kg/ha) (Chan et al. 1982). Reed canarygrass (*Phalaris arundinacea*), and other fast-growing grasses, however, accumulate metals in proportion to soil and water concentrations. The removal potential of reed canarygrass ranges from 0.001 kg/ha for cadmium to 0.69 kg/ha for copper. In *Phalaris*, unlike in other emergent macrophytes, translocation back to the belowground parts does not occur when the plant senesces. Instead, as the aboveground mass falls to the ground and decomposes, the accumulated pollutants and other compounds are gradually released back to the soil and water. Therefore, pollutant removal from this system would occur only through external harvesting (Chan et al. 1982).

Fauna

"In a comprehensive study of urban runoff in 22 cities, the EPA concluded that copper, lead, and zinc [the most prevalent toxic metals] in urban runoff posed a significant threat to aquatic life" (Baker 1992). The EPA later concluded that "high concentrations of these metals may bioaccumulate in fish and shellfish and impact beneficial uses of the affected waterbody" (EPA 1993a). The California Coastal Commission (Guidance Manual 1995) warns that heavy metals can "disrupt fish and shellfish reproduction, bioaccumulate in fish tissues, and can be passed up the food chain." The CCC further reports that human consumption of contaminated water, fish or shellfish can cause brain damage, birth defects, miscarriages, and infant deaths.

As with plants, different metals and metallic compounds have widely varying degrees of toxicity on wetland fauna. For example, the hexavalent form of chromium is highly toxic, while the trivalent form is relatively innocuous. Likewise, dissolved metals are more available to aquatic organisms than adsorbed metals. Copper, one of the more soluble metals, is frequently associated with fish kills and degraded aquatic habitats. Newton (1989) states that "in general, metals rarely have significant effects on stream water quality, adverse effects, like that of refractory organics, are usually significant only in areas of concentrated sedimentation, such as estuaries." It should, therefore, be noted that wetlands are also areas of concentrated sedimentation.

Studies on salt marshes suggest that particulate organics and their associated microorganisms are "one of the most important sinks for trace metals in aquatic environments" (Army Corps of Engineers 1986). Evidence exists that elements concentrated in these sinks are bioavailable. Results from experiments suggest that elevated concentrations of lead in the sediment microlayer can be available to marine biota, while wetland vegetation often acts as a source of zinc to organisms inhabiting adjacent waters. Cadmium, however, unlike lead and zinc, was not concentrated at the surface microlayer, but was organically bound with detritus and not readily transported to other trophic levels. A study by White and Cromartie (1985), as cited in Gambrell 1994, found that cadmium "did not accumulate in aquatic birds from a confined dredged material disposal site during periods when the facility contained ponded water. Presumably, this was due to much more effective immobilization of cadmium in soils and sediments during periods of reduction."

Finally, Knight (1992) warns that NPS discharges to wetlands are frequently above existing water quality criteria, and "may lead to water conditions that are potentially chronically toxic to invertebrates or larval fish, but that will not result in chronic toxic conditions for adult fish or birds." Therefore, important management decisions must be made regarding how much toxicity is "acceptable" to a wetland system, indicating that a "tradeoff" may be necessary if wetlands are to be used for water quality and wildlife.

Case Study - Urban NPS

Demonstration Urban Stormwater Treatment (DUST) Marsh, Fremont CA

"The Demonstration Urban Storm Water Treatment (DUST) Marsh was designed and constructed by the Association of Bay Area Governments (ABAG) in the early 1980's to study the processes of pollutant removal from urban runoff" (Wetzig 1995). It is located approximately 2.5 km east of south San Francisco Bay in Coyote Hills Regional Park. An historic wetland, reconstructed after many years of diking and filling, it is fed by Crandall Creek, an earthen flood control channel with limited vegetation. The DUST marsh consists of a series of 3 test basins, designed to evaluate various removal processes. In the following, I will summarize the results of several studies on the pollutant removal effectiveness of this system.

First study 1984-1986: Marsh effective in reduction of suspended solids, inorganic nitrogen, phosphorus, cadmium and lead, though only 30-40% vegetated at the time. The saline nature of local soils (flooding, saltwater intrusion, agricultural irrigation leaching) have led to high mineral, nutrient and heavy metal background concentrations. Evaluation of storm water pollutant contributions should be viewed in this context. Also, soil instability due to construction activities had apparently mobilized a number of substances (primarily metals) which showed up in water quality analysis.

Second study 1990-1991: Dissolved metal concentrations dropped sharply as water progressed through the marsh, with concentrations of metals in sediments significantly higher at Station 1 than at all the downstream stations. Limited sequential extraction analyses of sediments indicated that the estimated bioavailable fraction of metals (particularly zinc) decreased downstream within the system and was lowest in the marsh. Sediment concentrations of copper, lead, and zinc were low within the marsh and had low bioavailability. A comparison of sediment metal concentrations with control locations indicated a dramatic difference at the head of the creek, a small difference downstream within the creek, and comparable levels within the marsh. Crandall Creek was considered to be a linear wetland which functioned as a pre-treatment system for the marsh.

<u>Third study 1991-1992</u>: Copper, lead, and zinc concentrations, compared as dry weight, for the five most common plant species in the creek-marsh system revealed that *Echinochloa crusgalli* contained the highest concentrations, *Cotula coronopifolia and Cyperus eragrostis* had the next highest, and *Scirpus robustus and Typha spp.* were lowest, with roots containing higher concentrations than leaves. There was a significant positive correlation between total sediment copper, lead, and zinc and concentrations in combined plant data (with the strongest correlation in lead), indicating greater potential for uptake in sediments with higher metal concentrations. Metals introduced into Crandall Creek in stormwater were reduced within the first 625 feet from the point of discharge. Concentrations in water of total copper, lead and zinc in wet-weather flows were significantly reduced between Station 1 (Crandall Creek) and Station 9 (marsh discharge). Comparisons with data from previous years indicate a trend of decreasing concentrations of lead and stable concentrations of copper and zinc in sediments. This finding was particularly important since examination of metal concentrations for this 6-year period did not support the argument that the marsh was *accumulating* concentrations of metals, though the total *amount* of metals wase increasing due to sedimentation.

<u>Fourth study 1994</u>: Selenium concentrations in plants and fish were lower than background data for the area and were consistent with the low selenium content of soils in the watershed.

<u>Water Quality Study 1991-1992</u>: Monitoring survival (LT_{50}) and reproduction of water fleas (*Ceriodaphnia dubia*): toxicity was widespread throughout the marsh during most storm events of the year. Large storms were not fully-contained within the marsh system. Water became less toxic within 2-3 days following storm events. Direct inverse correlation between toxicity and conductivity. Vertical gradient of toxicity observed during inflow, with most toxic stormwater at the top of water column and decreasing toxicity with depth to denser saline resident water. This latter result supported the observation that incoming stormwater was flowing through the marsh with low retention time, allowing limited mixing of the incoming water with resident water, and limited exposure to marsh plants and soils. After a baffle was installed to block the surface flow

of the incoming storm water, the marsh began to retain toxic stormwater, and toxicity was reduced to undetectable levels in 2-3 days.

Animal study 1994: Studies on formerly translocated organisms (5 species of invertebrates, 2 species of fish) suggested that urban runoff pollution in this watershed did not have acute toxic effects on populations of resident animal species. There were four possible reasons for this: (1) natural populations, due to adaptive capabilities, could tolerate higher concentrations of pollution than lab animals; (2) natural populations could seek refuge away from toxic stormwater; (3) stormwater runoff during the experiment may not have contained toxic concentrations; (4) field experiments were subject to a variety of uncontrollable physical factors such as silt and temperature (induced some mortality), making the detection of chemical toxicity more difficult.

Diazinon study 1995: Evidence presented that the pesticide diazinon was a primary toxic pollutant in the marsh, but that the log boom baffle was effective in retarding outflow of toxic surface layers of water, thereby increasing the ability of the marsh to treat runoff.

Overall results of these previous studies: 1) the marsh did effectively reduce the toxicity of pollutants in stormwater, and 2) there was no net increase in the metal concentrations of sediments in the marsh, based on a 12-year time period.

> Schueler et al. (1992) found wetland treatment systems for stormwater to be one of the most effective of all available management practices. In addition, [the] evidence presented [by these DUST Marsh studies] does not support the hypothesis that these systems will turn into toxic 'hot spots' as a result of accumulation of persistent pesticides. However, this present evidence is based on 12 years of toxicant accumulation and questions still remain regarding results of longer-term accumulation (Wetzig 1995).

Based on the results of 12 years of study at this site, Wetzig offered several considerations and recommendations in the design of wetland treatment systems for urban runoff:

- Information phase: size of watershed; land use, developed vs open-space (permeability of surface); future plans for development; characteristics of incoming water conveyance system; quantity and velocity of incoming runoff; type and quantity of incoming stormwater pollution.

- Design phase: amount of resident water retained after storms should be adequate for continued well-being of biota; retention time of incoming storm water should be at least 3-4 days; mixing between incoming storm water and resident water should be enhanced; amount of wind exposure to surface water (mixing) should be maximized (except in initial pond); depth of water in marsh should be varied enough to offer temporary refugia for aquatic animals; amount of exposure of incoming stormwater to plants and soils should be maximized.
- Specific design characteristics to achieve these criteria: area of system should be between 1.1% and 2% of watershed area; pond construction in series of stages, each designed to enhance certain natural processes (eg. first pond deepest (3 m) to encourage settling out and reduce availability of contaminated sediments to biota, second pond 2 m, third pond 1 m. to allow for mosquitofish (*Gambusia*)); general direction of water flow should be opposite to direction of prevailing wind; islands promote mixing by increasing turbulence and serve as nesting sites for waterfowl; narrow vegetated channels interconnect ponds, promote mixing, and maximize exposure of incoming water to plants and soils; larger vegetation (willows and sycamores) physically direct prevailing winds along pond surfaces, shelter deep pond surfaces from wind, and provide shade to reduce water temperatures; log booms (baffles) disrupt flow of surface water on top of resident water, providing mixing of water strata and longer retention times of epilimnion; pre-construction monitoring (to provide baseline information), post-construction monitoring of water quality (water quality will improve upon "maturity"), fauna monitoring for at least 5 years to identify potential negative pollutant impacts.

Interpreting Results of Ongoing Studies

Chan et al. (1982) surveyed the pollutant removal effectiveness of a number of wetland-stormwater systems with respect to hydrology, climate, vegetation, water quality, and soils, which they present in Table 32 on pages 168-169 of their report. Though great dissimilarities exist between the various ongoing demonstration projects, certain conclusions can be drawn:

- Wide disparity exists in the NPS removal capacities of wetlands, particularly with regard to nutrients;
- The greatest consistency in pollutant reduction appears to be for biological oxygen demand, suspended solids, and heavy metals;
- Seasonal factors can have a major influence on the pollutant removal capabilities of certain wetlands.

DESIGN AND MANAGEMENT OF NPS WETLANDS

Fisher (1990) characterizes constructed wetlands as:

> Low-loaded biological fixed-film filters with inbuilt sedimentation. Whilst the emergent plants absorb some of the pollution directly, the main function of the plants is to supply oxygen to the microorganisms within the wetland. An appreciation of the hydraulic regime and actual detention time is a prerequisite to the understanding of the treatment mechanisms and the effectiveness of the purification provided. Mixing characteristics of the hydraulic regime determine whether a pollution concentration gradient occurs. This affects the regions in which particular biochemical reactions can occur and influences the rate of reaction. Hydraulic 'dead spots' may pool certain pollutants in particular zones, and short-circuiting due to the existence of preferred flow paths through the porous substratum may minimize the necessary contact between the effluent and the microorganisms in the plant root zone.

Design Criteria

According to van der Valk and Jolly (1992), the single most important factor affecting a treatment wetland is its size. "In operational terms, the size of a wetland should be determined by the expected total mass of various contaminants in the runoff entering it during some period, and the tolerable or sustainable loading of these various contaminants per unit area of wetland." Both are difficult to quantify. Precipitation events are highly variable seasonally and interannually, and sustained loading parameters for each contaminant are different, and poorly understood. Turnover time is a function of precipitation patterns, wetland size, location of inflows and outflows, and flow patterns within the wetland.

Chan et al. (1982) outlines some important processes affecting pollutant removal:

- Meandering channels, with slow-moving water and large surface areas, enhance settleable pollutant removal by sedimentation;
- Seepage wetlands or shallow flow regimes are effective for removal of pollutants such as phosphorus and metals by adsorption to the soil;

- Because many plants are selective in their accumulation and biomagnification of various heavy metals, mixed stands of vegetation may provide the best overall heavy metal removal;

Therefore, varied or mixed wetland systems containing features of ponding for sedimentation, shallow areas for adsorption by soil, and mixed vegetation, have high potentials for treating typical primary level municipal wastewaters with significant concentrations of many pollutants.

Kusler and Kentula (1989) suggest other design and management features that may enhance pollutant removal from treatment wetlands:

- Establishment of buffers to protect the wetland from sediment, excessive nutrients, pesticides, foot traffic, or other impacts from adjacent lands;
- Adoption of point and NPS controls for streams, drainage ditches, and runoff flowing into wetlands;
- Periodic dredging of certain portions subject to high rates of sedimentation (stormwater facilities).

Site Selection

Site selection is a critical element in the construction of a stormwater wetland, since hydrology, substrate, and land use patterns are all intimately tied to geographic location. Mitsch and Gosselink (1993) enumerate some important criteria in the site-selection process:

1. Find a site where wetlands previously existed or where nearby wetlands still exist. This increases the probability of proper substrate, seed sources, and hydrology;
2. Consider surrounding land use and future plans for surrounding land;
3. Perform a detailed hydrological study, including a determination of potential interaction of groundwater with the wetland;
4. Find a site where natural inundation is frequent. Determine the annual and extreme-event flooding history as closely as possible;

5. Inspect and characterize soils in some detail, not only to determine their permeability and depth, but also to determine their chemical content;
6. Determine the quality of groundwater, surface flows, flooding streams and rivers, and tides that may influence the site water quality. Chemicals in the water may be significant either to wetland productivity or to the bioaccumulation of toxic materials;
7. Evaluate on-site and nearby seed banks to ascertain viability and species distribution. Encourage plant species that maximize transformation and degradation of the pollutants of concern;
8. Predict wildlife usage and biotic makeup, including ecological corridors such as migratory flyways or spawning runs. Consider the position of the proposed wetland in the landscape. For example, a forested wetland island created in an otherwise grassy or agricultural landscape will support far different species from those that inhabit a similar wetland created as part of a large forest tract;
9. Ensure that an adequate amount of land is available to meet objectives. For example, "if aging of a wetland, defined as an impairment of wetland function after several years of perturbation, is anticipated because of the inputs of sediments, nutrients, or other materials, then larger land parcels to build additional wetlands in the future should be considered.

Hydrology

Hydrology essentially determines wetland function. The several parameters used to describe the hydrology of created and restored wetlands include hydroperiod, depth, and seasonal pulses; those for water quality wetlands include inflow rates, retention time, and basin morphology. Wetlands that possess a variety of water depths have the most potential for developing a diversity of plants, animals, and biogeochemical processes. Deepwater areas, devoid of emergent vegetation, offer habitat for fish and other wildlife, can enhance nitrification, and can provide low velocity areas where water flow can be redistributed. Open water areas should not be connected along the flow path, but rather interspersed with densely vegetated shallow marsh habitat. Shallow areas can provide maximum soil-water contact for certain chemical reactions such as denitrification, and can accommodate a greater variety of vascular plants (Mitsch and Gosselink 1993; Knight 1992). Table 30, pages 143-145, in Chan et al. (1983), is a valuable illustration of the relationships between the pollutant removal processes sedimentation, aeration, biochemical transformations, and soil adsorption, and the hydrological factors velocity and flowrate, water depth and fluctuation, detention time, circulation and flow distribution, circulation and flow distribution, turbulence and wave action, seasonal and climatic factors, soil saturation, permeability, and groundwater movement.

Loading Rates

The assimilative capacity of a wetland for an organic chemical is related to the chemical's biodegradability and volatility. "Models for estimating the assimilative capacity of wetlands for toxics are not available, and estimates are crude, at best" (Novotny and Olem 1994). These authors claim that "since hydraulics are the same for surface-water bodies with a significant sediment component, the U.S. EPA's water quality WASP may be used" to model loading rates. Few studies exist on the optimum design rates for NPS and stormwater runoff. The initial design for the Des Plaines River Wetland Demonstration Project called for an inflow rate of 1-8 cm/day. These values were estimated from rates for comparable wastewater wetlands, however, and may be too low for riparian wetlands receiving floodwaters (Mitsch and Gosselink 1993).

Baker (1992) observes that even though pollution constituents may vary, constructed wetlands for the treatment of cropland runoff have much in common with wetlands for urban runoff, since their designs for maximum pollutant removal are based "upon the need to retain sediments during peak flows." Since safe loading rates to wetlands, and the long-term effects of sub-acute levels of contaminants to wildlife, are virtually unknown, extreme care must be taken to minimize all potential impacts.

Substrata

A number of authors advocate the use of local soils, underlain with an impermeable subsoil layer to prevent downward percolation and reduce seepage losses.

The Water Pollution Control Federation (1990, cited in Novotny and Olem 1994) recommends a maximum substrate infiltration rate of approximately 1 mm/hr. These rates may be achieved by ensuring a subsoil rich in clay. However, since an impermeable clay layer may limit root and rhizome penetration, an overlay of local coarser texture (loam) soil is often the best design. If on-site topsoils are to be returned to the wetland after sealing the substrata, adequate temporary storage should be provided, and replacement made carefully, avoiding heavy equipment which might the compact the topsoil overlay and reduce its hydraulic conductivity. In addition, scarification, the creation of a cracked substrate at the soil-water interface, is a useful technique for improving moisture retention and reducing compaction (Novotny and Olem 1994; Mitsch and Gosselink 1993; USDA-SCS Engin. Field Handbook 1992; Wood 1990; Willard et al. 1989).

Flora

As mentioned previously, vegetation should be tailored to maximize degradation of target contaminants, utilizing a diverse array of indigenous species whenever possible. Monocultures can be utilized where heavy loading of toxics are expected, but "extreme caution must be exercised to avoid concentrations of contaminants to harmful levels" (USDA-SCS Engin. Field Handbook 1992). An adequate stand of plants can be expected to develop within 6-12 months after planting, though it may take 3-4 years for the stand to become fully developed with an active rhizosphere capable of achieving full treatment function (Wood 1990). "Extreme water level fluctuations severely hamper the ability of a fringe wetland to stabilize shorelines [and retain sediments and adsorbed metals] by making it difficult for vegetation to establish and maintain itself" (Levine and Willard 1989). Some species do succeed temporarily under these conditions. In a study of two reservoirs whose water level fluctuations averaged 3.5 m over a 6-year period, reed canarygrass (*Phalaris arundinacea*), Garrison creeping foxtail (*Alopecurus arundinaceus*), common reed, giant bulrush, and broad-leaved cattail all became established and survived for 1-3 years.

Vegetated Buffer Strips

Vegetated buffer strips "increase wetland productivity by separating a restored or enhanced wetland from other areas of incompatible use" (USDA-SCS Engin. Handbook 1992). These strips have been shown to improve plant diversity, cover, and food sources; prevent undesirable access to wetlands; lower temperature fluctuations; inhibit encroachment by farm machinery; and reduce erosion of overland NPS. Thus, the overall "net effect of the buffer strip is improved performance and longevity of the wetland" (DeLaney 1995).

"Frequently, pesticides that are washed from croplands by rainfall and cause adverse impacts on adjacent waters come from fields where a wetland buffer strip was not maintained. In these instances, water quality problems and even fish kills may be a consequence of the loss of the wetland" (Rodgers and Dunn 1992). Herbicides and copper-based materials, mobilized by runoff events, may kill buffer vegetation. However, depending on the vegetation structure, the buffer strip is likely to be more amenable to recolonization or seeding than the wetland (DeLaney 1995).

The dimensions and vegetation configuration of a buffer zone will depend on the area of the discharging watershed. A 1:1 ratio and a minimal width of 100 feet can capture approximately 80% of sediment discharged from a watershed. High vegetation densities for all strata (graminoid, herbaceous, shrub, tree) provide the most effective removal of contaminants. These reported values depend also, of course, on the slope, vegetation density, soil type, and meteorological events (DeLaney 1995).

Novotny and Olem, incorporating the recommendations of several leading ecological engineers, have compiled ten basic principles of ecological engineering for the restoration and creation of wetlands:

1. Design for minimum maintenance;
2. Utilize natural energies, such as the potential energy of streams;
3. Consider the landscape. Best sites are where wetlands existed previously, or where nearby wetlands still exist. Mimic nature. Avoid overengineering (avoid structures, unnatural shapes of basins, uniform depths, regular morphology);

4. Consider surrounding lands and future land-use changes;
5. Hydrologic conditions are paramount. A detailed surface- and ground-water study is necessary;
6. Chemical composition of feed waters, including ground-water discharge, can be significant to wetland productivity and/or bioaccumulation of toxics;
7. Soils should be surveyed. Highly permeable soils do not support viable wetland systems;
8. Design a system as an ecotone: buffer strips around wetlands, consider the wetland itself as a buffer between uplands and the aquatic system to be protected;
9. Riparian wetlands present a particular problem since flooding causes scouring, sediment shifts, erosion and deposition. Convex sides of river channels may be preferable due to higher erosive forces on concave sides;
10. Give the system time.

Management

A survey of wetland experts and stormwater managers in 1988 revealed that while most agreed that wetlands could indeed treat stormwater, and 78% were conditionally in favor of such use, almost all highlighted the need for maintenance: 41% identified the removal and disposal of sediment as a primary long-term maintenance item; 38% recommended long-term monitoring of overall pollutant control effectiveness; 28% called for vegetation monitoring; 17% stressed water-level management; 10% urged the development of a contingency plan; and 7% underscored the need for effective design, with specific provisions to minimize maintenance issues. These concerns implied certain risks to the receiving wetland, risks that may not be compatible with wetland protection and preservation programs (Newton 1989).

"While some wetlands have been shown to improve the quality of stormwater in some respects, without intensive management (and sometimes with it) these systems are subject to major habitat transformations, [invoking] serious questions concerning their long-term ability to function as originally planned" (Newton 1989). He cautions that:

- Raw stormwater should not be allowed to pass untreated into wetland ecosystems (there must be some means of removing sediment);
- Methodologies such as grassed swales or porous pavement should be encouraged;
- Some method of long-term maintenance must be established (sediment removal from trapping systems, control of vegetation of grassed swales, and ecological monitoring of receiving wetlands);
- Contingencies (emergency bypass, storage basins, etc.) against accidental or unpredicted discharges of toxics should be developed;
- On-site reduction of stormwater flow and pollutants should be the ultimate goal.

Wetzel (1993) offers some specific design features to maximize a wetland's retentive or processing functions:

- Macrophytes should be kept in r-growth stages by intentional, programmed disturbances;
- Multi-species diversity is generally more responsive to loading variations than are monocultures;
- Detrital and sediment surface areas should be maximized to enhance microbial growth and sedimentation/storage functions;
- Anaerobic conditions generally maximize overall retention of both organic matter and the nutrients contained within it;
- Hydrology should be used to maximize microbial access to dissolved organic matter, growth, and storage functions. (This is one area in which constructed wetlands could greatly improve over the generally channelized hydrology of wetlands under natural conditions.)
- Alternative electron acceptors to oxygen could be added to constructed wetlands, along with other catalysts like silt, ash, soil, or peat, to manipulate pH and precipitation, in order to maximize retention.

If mosquitoes become a problem, several studies recommended the use of mosquitofish, (*Gambusia sp.*) providing that some ponds remain aerobic, and that fish can migrate from the pools into other parts of the wetland. One method, developed by Hruby (cited in Novotny and Olem 1994) consists of a wetland-ditch combination. The ditches create narrow reservoirs in which water levels are manipulated to permit fish to enter marshes to spawn. Newly hatched fish larvae then feed on mosquito larvae. Up to 97% mosquito control was reported using this method.

Though several authors have advocated dredging to remove sediments from wetland basins, this is generally an expensive operation, which not only removes sediments, but the seed bank, rooted plants, and sediment-associated organisms as well. Another important consideration is the placement of the contaminated sediments, which may be subject to regulation as toxic waste. We have already seen that placement of wetland soils in upland conditions can result in substantial leaching of toxics as they are released from their bound forms via oxidation. Mitsch and Gosselink (1993) advocate that, unless dredging is unavoidable, the best approach is to accept the accumulation as a natural part of wetland dynamics.

Long-Term Treatment Capacity

"Studies have shown that wetlands can be very effective in the reduction of suspended solids and heavy metals from wastewater, however, very little information has been collected on the use of wetlands over extended time periods in the treatment of stormwater runoff" (Fisk 1989). Wetlands can become saturated with pollutants, depending upon the wetland type, hydrologic conditions, pollutant constituents, and the length of time that the wetland has been subjected to such loadings. When the ecosystem becomes saturated with toxics, they many begin to increase in the effluent. "Permanent long-term storage depends in part on whether the wetland is accreting vertically (and thus sequestering materials in deep sediments" (Mitsch and Gosselink 1993).

Nevertheless, Fisk asserts that "with proper design, an isolated wetland can be used to treat stormwater runoff by natural means without damaging the existing ecosystem in perpetuity. In fact, the addition of stormwater can help to maintain existing hydroperiods and provide additional nutrients which could possibly increase the productivity of the wetland with improved wildlife habitat." He also advises, however, that additional testing is needed, and that wetland systems should be closely monitored if they are receiving pesticides, herbicides, and fertilizers.

In the limited studies available, all of the "older" (approximately 60 year old) wetland projects studied appeared to be renovating waste water and retaining toxic constituents, with the greatest uncertainty occurring for total dissolved phosphorus (Kadlec and Kadlec 1979). Other studies have found that phosphorus achieves saturation readily and is usually the element most often exported from wetlands. However, after 30 years of heavy storm and wastewater discharges, removal rates for phosphorus and total suspended solids for Lake Munson, receiving urban NPS from Tallahassee FL, are similar to those expected from relatively new wet detention ponds having similar dimensions and loading rates (Fisk 1989).

In general then, a review of the literature suggests two broad conclusions:

1. Wetlands exposed to pollutants often act in ways similar to terrestrial and aquatic systems: species abundance and diversity can be affected, at least temporarily; energy transmission through food webs can change; and functional parameters, resource quality, and habitat quality at the landscape level can deteriorate rapidly or subtly;
2. The lack of agreement between existing studies on specific fates and effects of pollutants on wetland processes suggests that there is little meaningful generality in wetland ecotoxicology (Catallo 1993).

Catallo summarizes by claiming that:

> To a large degree, we are stuck with a lack of data explicitly dealing with toxicant effects on wetland ecology, and a major challenge for the future is to provide the needed work with a view toward understanding the functional alteration of landscapes by contaminants. This challenge involves not only the development of new techniques and concepts, but also the examination of specific wetland types as organs within extended living systems, rather than as totalities studied in isolation.

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Appendix 4

Water Quality Monitoring Data Report

Watershed Monitoring Program

The primary goal of this watershed monitoring program is to determine the effectiveness of restored wetlands as a biological filter of non-point source pollution by creating a water quality database for those areas before (or during) and after restoration. To determine any water quality improvements, it is necessary to take samples at the point of input into a restoration area, and at the exit point. Sites that did not have an identified input or exit area, such as at the headlands of a watershed, could not be included in this sampling design. Sample sites were designated above and below four restoration areas, and at three of the areas an additional site was included at the middle of the water course through the restoration.

A reference location was also sampled during the 1995-1996 rain season to compare restored wetland areas to a yet un-restored system. The reference area along the Castroville Slough is presently a drainage ditch similar to the restoration sites before restoration activities began. The slough flows into the Moro Cojo Slough and is of a similar length as the restoration areas. The site has been designated for future restoration activity and these data are additionally useful as historical information for future restoration projects.

Restoration areas included in the monitoring program are Natividad Creek Park, Hansen Slough, Moon Glow Dairy, and Walker Valley Creek. Castroville Slough was included as the reference location. Additional measurements were taken periodically, at the Calcagno Marsh Restoration on the Moro Cojo Slough and the Mo's Restoration on the Tembladera Slough, to gain background information on other local drainage areas. More extensive monitoring of drainage systems not under active restoration was determined to be an inappropriate use of resources by the Technical Advisory Committee for the complimenting SWRCB 205j contract. This advise was utilized to increased the number of samples at restoration sites from the projected 40 to 64 samples.

This quarterly report will review water quality monitoring data taken during the 1995-1996 winter rain period. A review of bivalve bioaccumulation and estimates of plant and animal abundance will be completed in future reports as the work is completed.

Methods:

Water samples were collected from designated locations with a five liter container for in-field measurements and a one liter bottle for future nitrate analysis. A Solomat Multiparameter Water Quality Probe field meter (Neotronics) was used to measure temperature (°C), conductivity (μS), pH, turbidity (NTU), and oxygen concentration (ppm) on site. Water samples for nitrate analysis, were spun in a centrifuge to remove most particulate matter, filtered with a 1 micron filter and frozen at -18 °c until the time of analysis. Nitrate measurements were made at Moss Landing Marine Labs using the cadmium column reduction method and estimated as μMoles and converted to ppm $NO3$.

Database Review

All data are presented in the accompanying database and database description (Table 2). Oxygen concentrations at all locations ranged from above saturation (+10ppm) to as low as 1ppm. Highest levels were generally associated with a spill-way which increased water mixing, and lowest levels were often associated with cattle runoff. Measured pH levels exceeded 8 on three occasions, also associated with cattle. Lowest conductivity levels were also from areas receiving cattle runoff. Temperature differed most between dates.

Turbidity and Nitrates

Hansen Restoration

Turbidity measurements at Hansen Restoration (Fig. 12) have demonstrated a significant decrease in sediment load as water passed through this restoration area. Turbidity decreased by as much as 50 fold from the monitoring station above the restoration to the station below the restoration. These decreases in turbidity were continuous throughout the winter rain season with one exception on February 29. This increase in turbidity in the upper half of the restoration is due primarily to physical berms successfully rerouting creek flow which caused some stream bed carving.

Nitrate concentrations similarly decreased as water passed through the Hansen Restoration area during all sample dates. Nitrate levels entering this restoration site exceeded 140ppm but levels leaving the area never exceeded 40ppm, and were frequently below 5ppm. Nitrate concentrations decreased steadily through the restoration area during all dates except slight increased at the middle station on January 31.

Natividad Restoration Park

Turbidity measurements (Fig 13) decreased as water passed through the Natividad Restoration site during the first two significant rain events. Levels increased however, during the next two rain events. This increase is possibly due to input from degraded side drainage systems along the Natividad Restoration drainage, but also probably due to continued rerouting of flow within the widened basin. Both possibilities suggest that this restoration site is not yet at full filtering potential. Further vegetative growth during this next season will most probably increase filtering potential.

Nitrate concentrations were commonly greater at the middle restoration site than the above restoration further suggesting inputs of degraded water being added to the drainage along its length. Nitrate concentrations were often less at the monitoring station below the restoration than the middle restoration station suggesting some uptake by the dense vegetation of the lower Natividad drainage.

Moon Glow Dairy Restoration

Turbidity measurements (Fig 14) were often greatest at the middle restoration monitoring site due to significant runoff from the dairy draining in at this location. Measurements were consistently below 100 NTUs at the lower drainage but consistent trends of filtering are variable due to the multiple input points from both dairy and agriculture runoff.

Nitrate measurements were surprisingly low at all monitoring locations, but highest levels were from agriculture runoff into the upper restoration area. While effluent from the dairy was pungent, nitrates levels were below 1ppm at all sampling periods other than Jan 31. Other forms of nitrogen such as ammonia or urea may have been very high but were not analyzed. Further analysis may be warranted for this site.

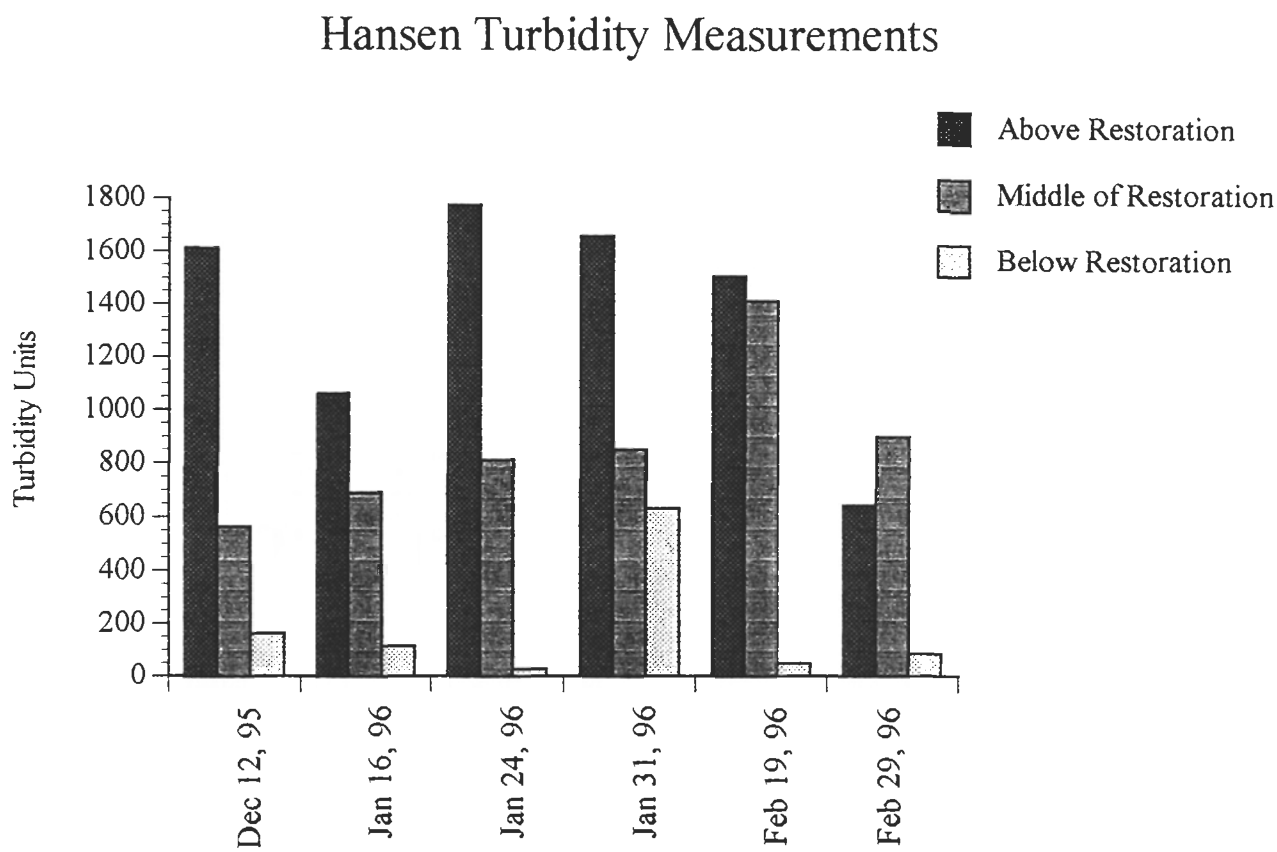
Walker Valley Restoration

All water flowing into the restoration area soaked into the wetland area before reaching the lower end of the site. All sediment and nitrates were therefore also absorbed into the system until February 19 (Fig 15). Turbidity levels increased during the last two sampling periods as water routed itself through the new wetland area. Nitrate levels in February were much lower than the previous periods when all water was absorbed into the system. Slight decreases in nitrate levels were also measured. No increases were measured from nitrates absorbed during previous rain events.

Castroville Slough Reference Site

The data from this reference location indicate that this unvegetated drainage ditch lacked the ability to filter or improve water quality (Fig 16). Turbidity levels remained similar at the two reference stations on all three dates demonstrating no filtering of sediment loads. Nitrates however increased considerably from the upper to the lower reference locations. Data were not taken at the appropriate site for comparison on December 12, 1995.

Figure 12


Hansen Turbidity Measurements
Above Restoration
Middle of Restoration
Below Restoration
Turbidity Units
1800
1600
1400
1200
1000
800
600
400
200
0
Dec 12, 95
Jan 16, 96
Jan 24, 96
Jan 31, 96
Feb 19, 96
Feb 29, 96

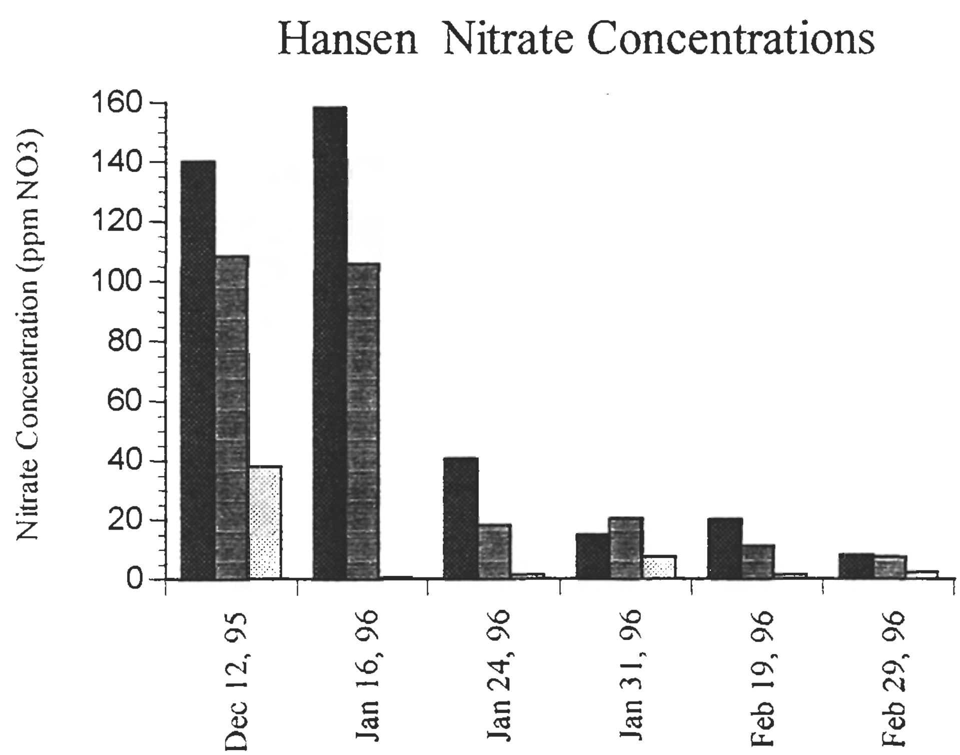
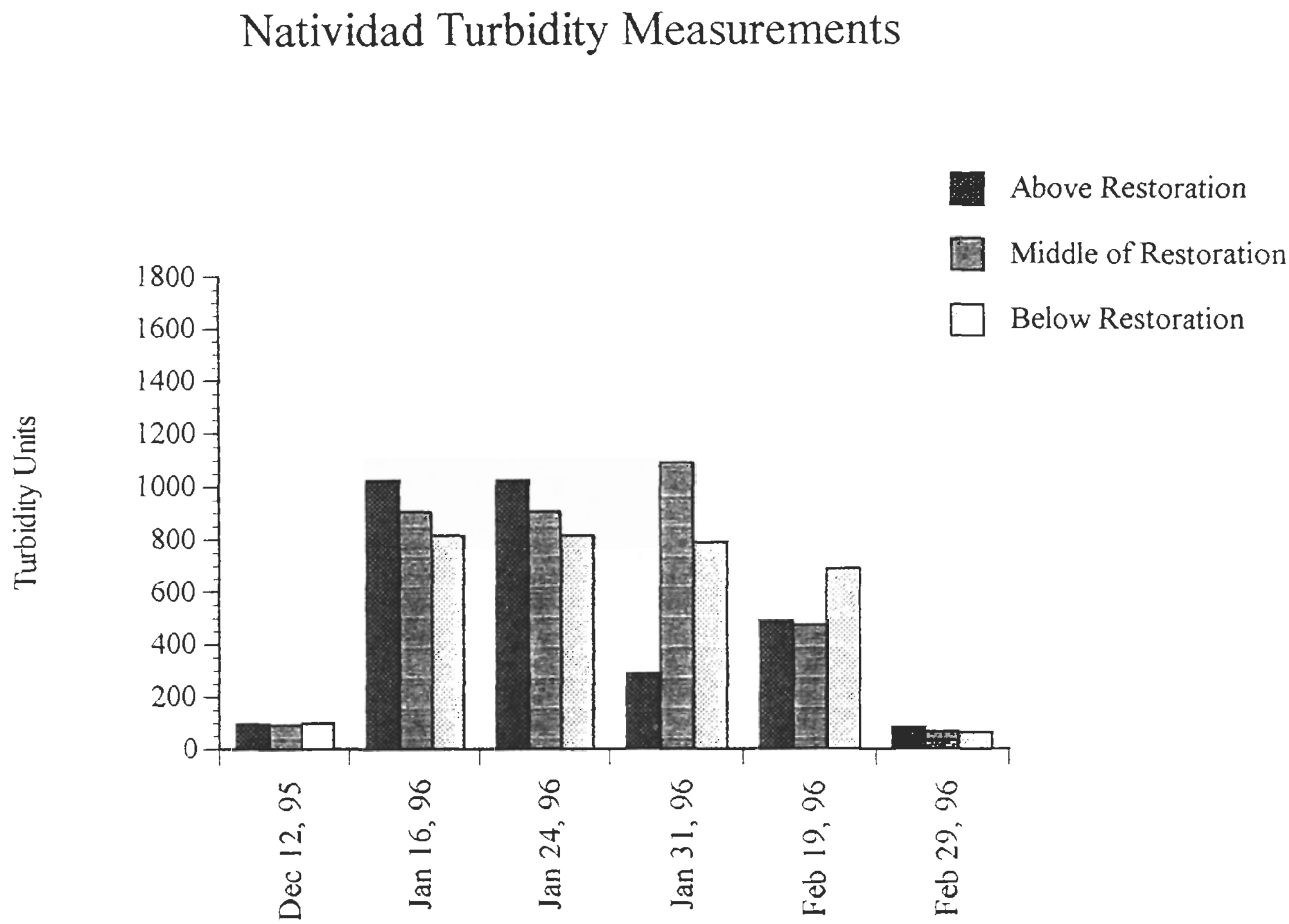
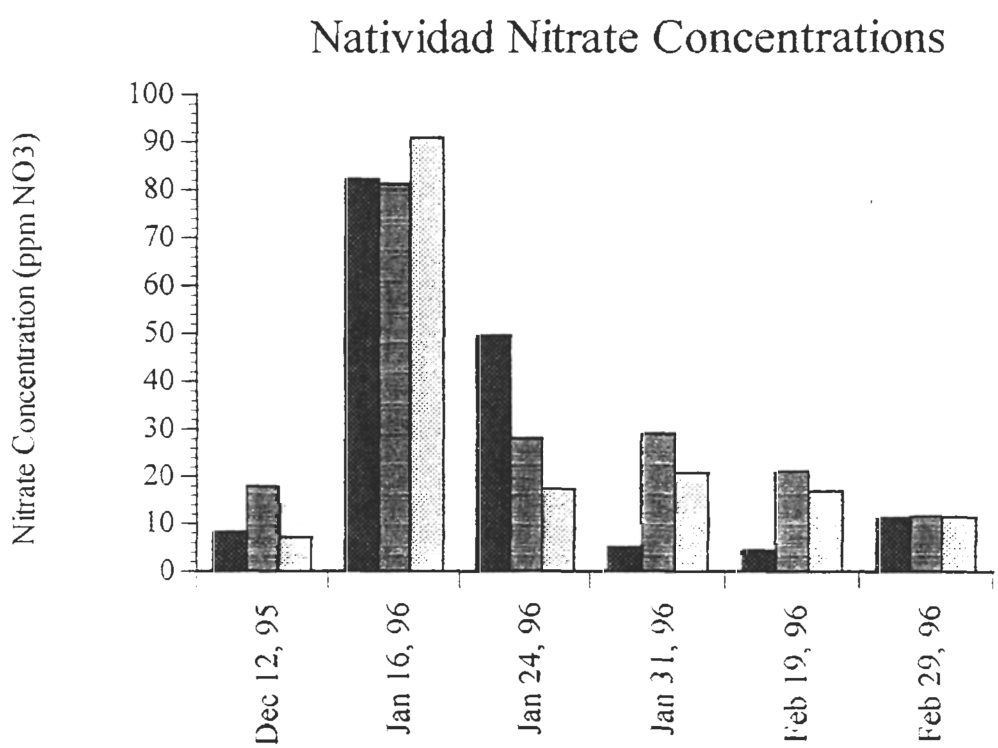

Hansen Nitrate Concentrations
Nitrate Concentration (ppm NO3)
160
140
120
100
80
60
40
20
0
Dec 12, 95
Jan 16, 96
Jan 24, 96
Jan 31, 96
Feb 19, 96
Feb 29, 96

Figure 13

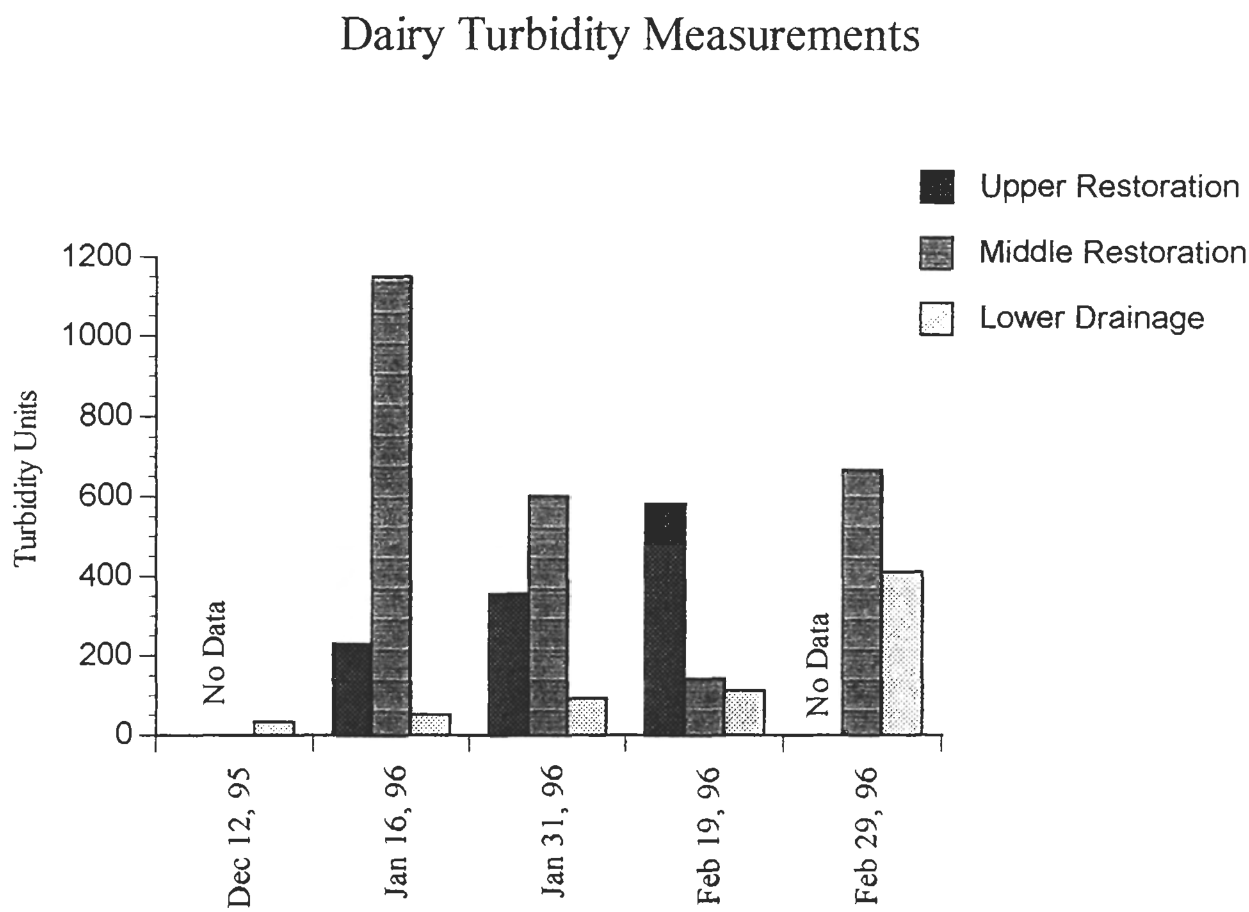


Natividad Turbidity Measurements
Above Restoration
Middle of Restoration
Below Restoration
Turbidity Units
1800
1600
1400
1200
1000
800
600
400
200
0
Dec 12, 95
Jan 16, 96
Jan 24, 96
Jan 31, 96
Feb 19, 96
Feb 29, 96



Natividad Nitrate Concentrations
Nitrate Concentration (ppm NO3)
100
90
80
70
60
50
40
30
20
10
0
Dec 12, 95
Jan 16, 96
Jan 24, 96
Jan 31, 96
Feb 19, 96
Feb 29, 96

Figure 14


Dairy Turbidity Measurements
Upper Restoration
Middle Restoration
Lower Drainage
Turbidity Units
1200
1000
800
600
400
200
0
No Data
No Data
Dec 12, 95
Jan 16, 96
Jan 31, 96
Feb 19, 96
Feb 29, 96

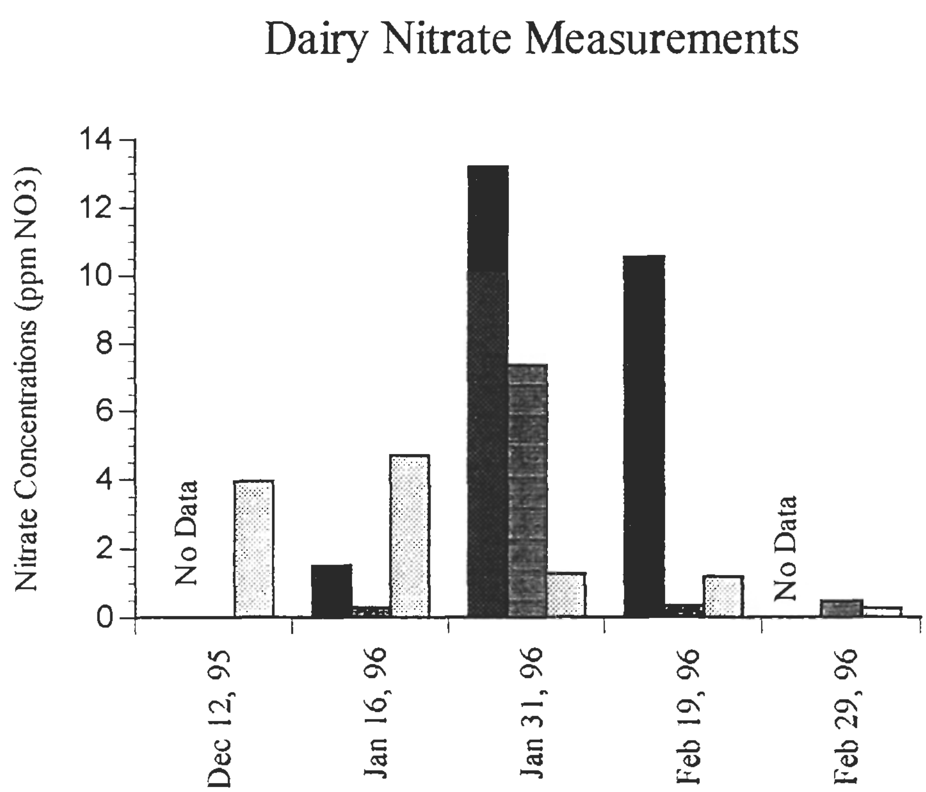
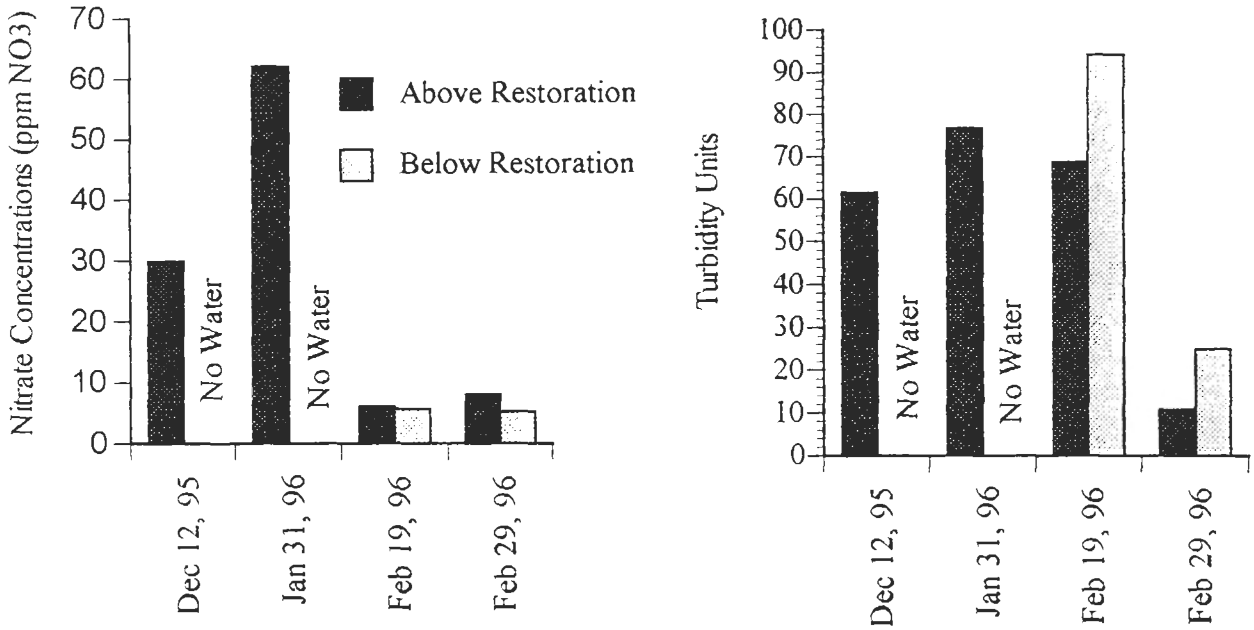
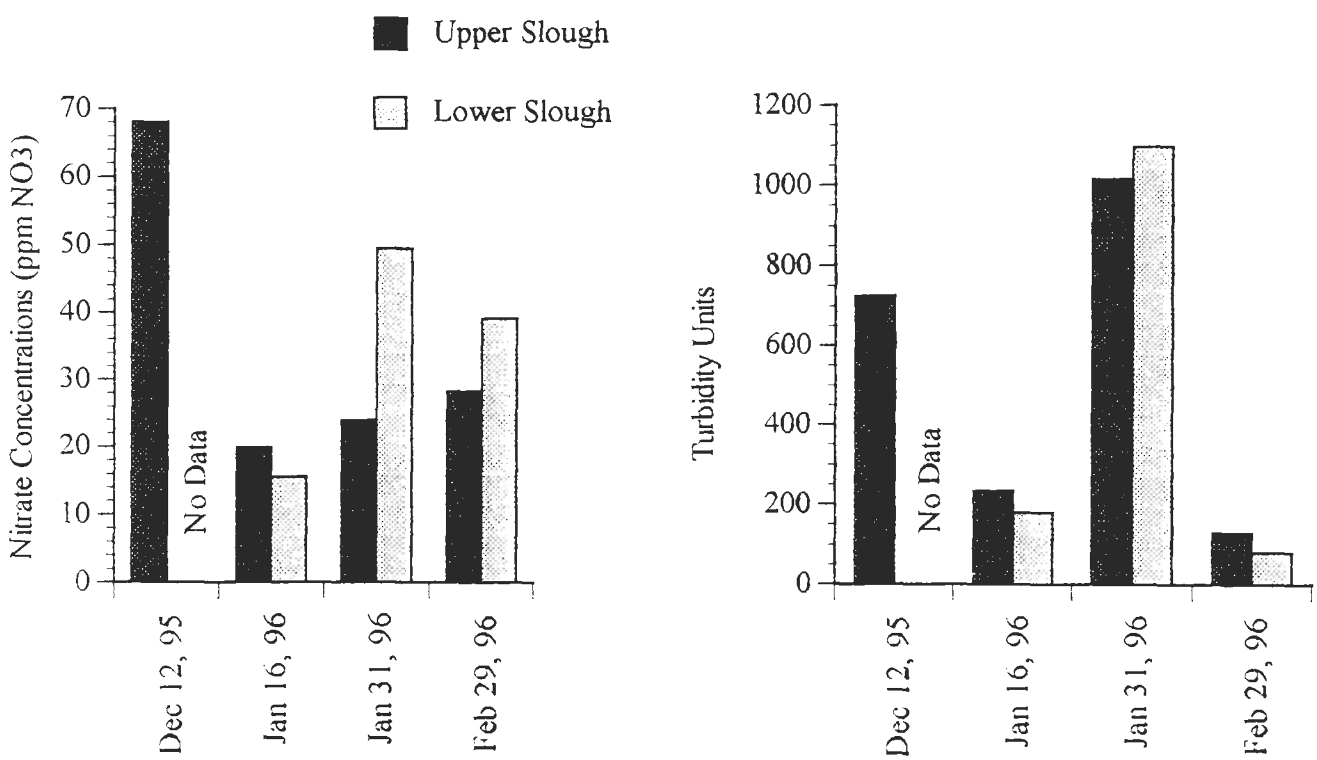

Dairy Nitrate Measurements
Nitrate Concentrations (ppm NO3)
14
12
10
8
6
4
2
0
No Data
No Data
Dec 12, 95
Jan 16, 96
Jan 31, 96
Feb 19, 96
Feb 29, 96

Figure 15

Walker Valley Restoration



Castroville Slough Reference Site



Data Base Description

Sta_num	Site identification number
Station	General area of sample
Date	Date sample taken
Ref_no	Individual sample identification number
Location	Specific site within that Station
Oxygen	Oxygen as ppm
pH	pH
Temp.	Temperature as centigrade
Conductivity	Conductivity as µS
Turbidity	Turbidity as NTU
NO3_um	Nitrates as micromoles
NO3_ppm	Nitrates as parts per million NO3

Table 2.

STA_NUM	STATION	DATE	REF_NO	LOCATION	OXYGEN	PH	TEMP	CONDUCT	TURBIDITY	NO3_UM	NO3_PPM
10	CALCAGNO	12/12/95	67.0	UPPER					20.3	176.5	9.18
12	CALCAGNO	12/12/95	68.0	ARTICHOKE FD					131.7	2955.1	153.67
14	CASTROVILLE SLOUGH	12/12/95	69.0	CHANNEL					724.0	1307.6	68.00
17	DAIRY	12/12/95	70.0	LOWER					32.4	76.1	3.96
4	HANSENS	12/12/95	61.0	UPPER					1614.0	2697.5	140.27
5	HANSENS	12/12/95	62.0	MIDDLE	Data Not Collected				566.0	2086.7	108.51
6	HANSENS	12/12/95	63.0	LOWER					162.0	732.2	38.07
1	NATIVIDAD	12/12/95	64.0	UPPER					93.1	156.9	8.16
2	NATIVIDAD	12/12/95	65.0	MIDDLE					88.7	342.0	17.78
3	NATIVIDAD	12/12/95	66.0	LOWER					97.9	134.8	7.01
18	TOTTINO	12/12/95	60.0	MARSH					56.1	430.0	22.36
7	WALKER VALLEY	12/12/95	71.0	UPPER					61.4	575.3	29.92
14	CASTROVILLE SLOUGH	1/16/96	78.0	CHANNEL	3.33	7.15	14.6	499.0	234.0	382.6	19.90
15	DAIRY	1/16/96	84.0	UPPER	10.17	7.98	14.7	757.4	230.0	29.1	1.51
16	DAIRY	1/16/96	83.0	MIDDLE	1.03	8.34	14.8	2.8	1150.0	5.2	0.27
17	DAIRY	1/16/96	82.0	LOWER	8.48	7.48	14.3	177.8	50.7	90.1	4.69
4	HANSENS	1/16/96	72.0	UPPER	7.99	7.78	14.5	1251.0	1063.0	3046.3	158.41
5	HANSENS	1/16/96	73.0	MIDDLE	3.75	7.19	14.3	1086.5	691.0	2037.2	105.93
6	HANSENS	1/16/96	74.0	LOWER	4.25	6.97	12.8	915.1	115.0	10.7	0.56
21	MO'S	1/16/96	81.0		5.95	7.58	13.6	1029.3	836.0	496.1	25.80
1	NATIVIDAD	1/16/96	75.0	UPPER	9.28	7.27	13.6	577.0	1020.0	1580.3	82.18
2	NATIVIDAD	1/16/96	76.0	MIDDLE	8.06	7.09	13.4	555.4	903.0	1561.2	81.18
3	NATIVIDAD	1/16/96	77.0	LOWER	8.20	7.16	13.7	602.0	814.0	1745.0	90.74
18	TOTTINO	1/16/96	79.0	MARSH	9.78	8.06	14.1	8.1	64.0	3884.0	201.97
19	TOTTINO	1/16/96	80.0	CHANNEL	6.89	7.41	14.3	681.5	177.0	298.9	15.54
4	HANSENS	1/24/96	88.0	UPPER	9.2	7.50	11.8	574.7	1776.0	780.6	40.59
5	HANSENS	1/24/96	89.0	MIDDLE	5.7	7.21	11.6	1057.0	813.0	347.5	18.07
6	HANSENS	1/24/96	90.0	LOWER	6.4	7.03	10.7	876.3	24.6	28.2	1.47
1	NATIVIDAD	1/24/96	85.0	UPPER	8.6	7.24	11.0	717.0	190.0	952.0	49.50
2	NATIVIDAD	1/24/96	86.0	MIDDLE	9.0	7.55	11.2	608.0	93.0	537.9	27.97
3	NATIVIDAD	1/24/96	87.0	LOWER	8.6	7.61	11.7	628.0	68.6	333.2	17.33
14	CASTROVILLE SLOUGH	1/31/96	98.0	CHANNEL	6.6	7.93	13.3	274.0	1016.0	460.3	23.94
15	DAIRY	1/31/96	99.0	UPPER	6.6	7.21	12.7	207.1	356.0	253.6	13.19
16	DAIRY	1/31/96	101.0	MIDDLE	3.6	7.01	12.4	560.7	601.0	141.3	7.35

Table 2.

STA_NUM	STATION	DATE	REF_NO	LOCATION	OXYGEN	PH	TEMP	CONDUCT	TURBIDITY	NO3_UM	NO3_PPM
17	DAIRY	1/31/96	100.0	LOWER	5.7	7.40	12.1	689.4	92.5	24.4	1.27
4	HANSENS	1/31/96	91.0	UPPER	6.8	7.48	11.9	527.5	1660.0	286.9	14.92
5	HANSENS	1/31/96	92.0	MIDDLE	5.3	7.17	11.8	430.6	851.0	388.5	20.20
6	HANSENS	1/31/96	93.0	LOWER	4.1	6.96	11.6	6.3	632.8	144.5	7.51
21	MO'S	1/31/96	104.0		6.1	7.41	12.3	405.1	1083.0	451.5	23.48
1	NATIVIDAD	1/31/96	94.0	UPPER	7.1	7.35	13.3	150.8	287.0	95.6	4.97
2	NATIVIDAD	1/31/96	95.0	MIDDLE	6.2	7.24	11.9	333.6	1088.0	555.9	28.91
3	NATIVIDAD	1/31/96	96.0	LOWER	6.4	7.32	12.5	268.2	787.0	400.5	20.83
18	TOTTINO	1/31/96	103.0	MARSH		7.65	12.6	766.1	879.0	729.3	37.92
19	TOTTINO	1/31/96	102.0	CHANNEL		7.78	13.2	560.6	1096.0	949.7	49.38
7	WALKER VALLEY	1/31/96	97.0	UPPER	6.3	7.00	11.5	447.6	76.7	1195.2	62.15
15	DAIRY	2/19/96	112.0	UPPER		7.09	14.7	201.3	582.0	203.0	10.56
16	DAIRY	2/19/96	113.0	MIDDLE		7.30	14.7	346.1	142.0	6.5	0.34
17	DAIRY	2/19/96	114.0	LOWER		7.23	14.8	426.7	111.0	22.8	1.19
4	HANSENS	2/19/96	106.0	UPPER		7.00	14.6	571.4	1506.0	384.8	20.01
5	HANSENS	2/19/96	107.0	MIDDLE	Data	7.12	14.5	655.8	1413.0	213.1	11.08
6	HANSENS	2/19/96	108.0	LOWER	Not	6.97	14.6	503.3	47.4	29.8	1.55
1	NATIVIDAD	2/19/96	109.0	UPPER	Available	7.48	15.1	131.7	485.0	82.9	4.31
2	NATIVIDAD	2/19/96	110.0	MIDDLE		7.08	14.6	367.4	470.0	402.6	20.94
3	NATIVIDAD	2/19/96	111.0	LOWER		7.57	14.8	306.9	687.0	325.6	16.93
7	WALKER VALLEY	2/19/96	115.0	UPPER		7.12	14.5	228.4	68.7	117.4	6.10
8	WALKER VALLEY	2/19/96	116.0	LOWER		6.96	14.3	246.7	94.1	108.2	5.63
14	CASTROVILLE SLOUGH	2/29/96	127.0	CHANNEL	7.76	6.68	13.8	818.0	130.0	542.5	28.21
15	DAIRY	2/29/96	121.0	MID-UPPER	5.69	8.17	13.6	4.6	830.0	11.3	0.59
16	DAIRY	2/29/96	122.0	MIDDLE	2.47	7.85	13.1	3.0	666.0	9.0	0.47
17	DAIRY	2/29/96	123.0	LOWER	2.64	7.90	12.7	3.4	410.0	5.0	0.26
4	HANSENS	2/29/96	118.0	UPPER	10.73	7.54	13.0	737.1	641.0	155.2	8.07
5	HANSENS	2/29/96	119.0	MIDDLE	8.64	7.40	13.4	780.3	898.0	143.7	7.47
6	HANSENS	2/29/96	120.0	LOWER	5.14	7.07	12.1	488.8	81.9	45.2	2.35
21	MO'S	2/29/96	128.0		8.95	7.43	11.7	1013.2	266.0	1311.3	68.19
1	NATIVIDAD	2/29/96	124.0	UPPER	10.70	7.50	12.7	527.6	81.0	214.6	11.16
2	NATIVIDAD	2/29/96	125.0	MIDDLE	9.98	7.65	12.8	530.4	64.9	220.6	11.47
3	NATIVIDAD	2/29/96	126.0	LOWER	10.20	7.79	13.0	534.5	63.0	220.6	11.47
19	TOTTINO	2/29/96	129.0	CHANNEL	9.90	7.64	11.8	3.1	80.0	751.0	39.05

Table 2.

STA_NUM	STATION	DATE	REF_NO	LOCATION	OXYGEN	PH	TEMP	CONDUCT	TURBIDITY	NO3_UM	NO3_PPM
7	WALKER VALLEY	2/29/96	129.5	UPPER	10.72	7.73	13.2	342.8	10.8	115.0	8.06
8	WALKER VALLEY	2/29/96	130.0	LOWER	8.67	7.19	12.3	329.3	24.8	101.4	5.27
0	DAIRY	3/13/96	0.0	MID-UPPER			Data Not Collected			6.3	0.33
0	TEMBLADERO	3/13/96	0.0	ARTICHOKE BN						601.5	31.28

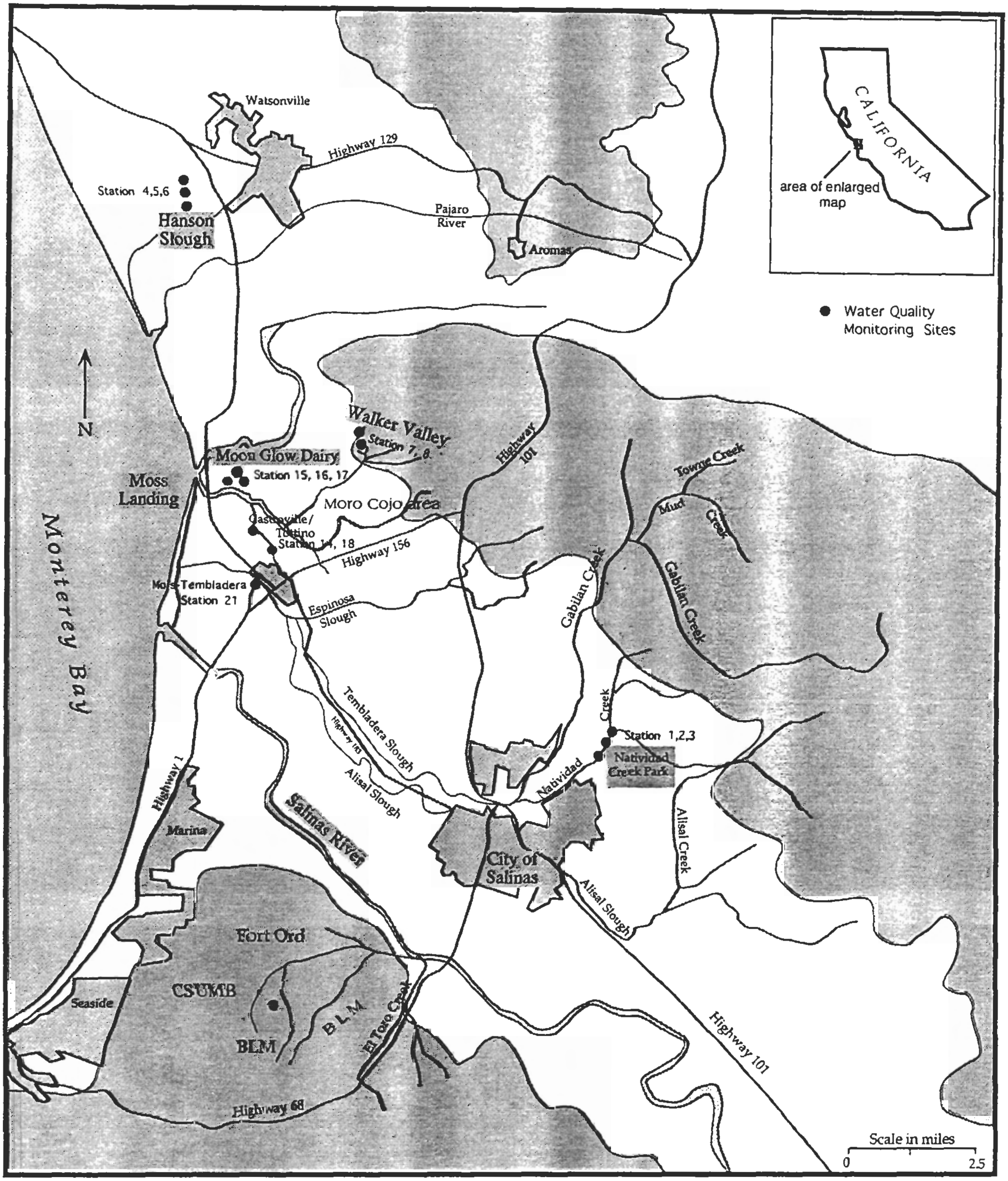


Figure 5: Dots indicate location where the Watershed Institute is monitoring water quality flowing through wetland restoration sites in the Monterey Bay area. Station numbers correspond with water quality database station numbers.

Historic Water Quality Monitoring

Data Tables

and

Sampling Location Maps

State Mussel Watch Program 1978-1993

TABLE 18

MUSSEL WATCH ORGANIC RESULTS THAT EXCEED NAS RECOMMENDATIONS
(ppb, wet weight)

STATION NUMBER	STATION NAME	DATE	SAMPLE TYPE	TOTAL DDT (1000)#	TOTAL PCB (500)#
401.80	SAN ANDREAS ROAD	11/26/86	FWC	1446	
405.00	ESPINOSA SLOUGH	11/28/83	FWC	2189	
405.40	OLD SALINAS R. CH.1	11/28/83	FWC	1551	
407.50	BLANCO PUMP EAST	02/19/85	FWC	3769	
407.50	BLANCO PUMP EAST	12/11/86	FWC	1086	
407.60	ML DRAIN BLANCO D/S	02/19/85	FWC	2350	
407.80	BLANCO-HITCHCOCK	12/11/86	FWC	2482	
408.90	REC. CANAL #3	12/11/86	FWC	1814	500
409.00	REC. CANAL #4	12/11/86	FWC	3249	
507.80	REVOLON SLOUGH	12/31/86	FWC	6174	854

\# = National Academy of Sciences (NAS) recommended guideline for freshwater organisms
FWC = Freshwater Clam

TABLE 19

MUSSEL WATCH ORGANIC RESULTS THAT EXCEED USFDA ACTION LEVELS AND TOLERANCE
(ppb, wet weight)

STATION NUMBER	STATION NAME	DATE	SAMPLE TYPE	TOTAL CHLORDANE (300)**	TOTAL DDT (5000)**	DIELDRIN (300)*	ENDRIN (300)*	TOTAL PCB (2000)***	TOXAPHENE (5000)**
303.30	LAURITZEN CANAL MID	01/14/87	TCM		12026	810			
401.80	SAN ANDREAS ROAD	11/26/86	FWC			324			
407.60	ML DRAIN BLANCO D/S	02/19/85	FWC			468			
408.90	REC. CANAL #3	12/11/86	FWC				300		
409.00	REC. CANAL #4	12/11/86	FWC			308	374		6572
507.80	REVOLON SLOUGH	12/31/86	FWC	305	6174				
894.00	SD BAY E. COMM. BASIN	12/29/82	TCM					3792	
894.00	SD BAY E. COMM. BASIN	02/19/85	TCM					2412	
894.00	SD BAY E. COMM. BASIN	01/03/86	TCM					2208	
894.10	E. BASIN SOFT BOTTOM	01/04/84	TCM					2014	

* = FDA action level for fish and shellfish
** = FDA action level for fish only
*** = FDA tolerance for fish and shellfish

TCM = Transplanted California Mussel
FWC = Freshwater Clam

APPENDIX F (continued)

State Mussel Watch Program

Summary of 1987-93 Data: Organic Chemicals Exceeding Selected Criteria (ppb, wet weight)

Station Number	Station Name	Sample Type*	Sample Date	Aldrin	Chlor-ben-side	Total Chlor-dane	Chlor-pyrifos	Dacthal	Diaz-inon	Total DDT	Di-chloro-benzophenone
401.9	Pajaro River Estuary	TFC	03/10/93								
402.1	Azevedo Pond	TCM	02/25/93					6.3**			20.0**
402.2	Parson's Slough	TCM	03/02/88					4.8*			
402.2	Parson's Slough	TCM	01/04/89					4.6*			
402.2	Parson's Slough	TCM	02/25/93				3.7**	25.0**			
402.3	Elkhorn Slough/Pacific Mariculture	TCM	01/04/89					5.4*			
402.5	Elkhorn Slough/Tidal Pond	TCM	02/25/93					22.0**			
403.0	Elkhorn Slough/Highway 1 Bridge	TCM	03/02/88					1.6*			
403.0	Elkhorn Slough/Highway 1 Bridge	TCM	01/04/89					1.0*			
403.2	Moro Cojo	TCM	01/04/89					8.4**			

Station Number	Dicofol	Diel-drin	Total Endo-sulfan	Endrin	Ethion	alpha-HCH	beta-HCH	delta-HCH	Gamma-HCH	Hepta-chlor	Hepta-chlor-epoxide	Hexa-chloro-benzene
401.9					2.7**				0.7*			
402.1		47.0**	12.2*	1.7**							2.0**	
402.2			44.2*									
402.2			47.1**								0.2*	
402.2		24.0**	17.8*	2.5**							0.7**	
402.3			23.7*								0.3*	
402.5		20.0**	17.6*	3.4**							2.2**	
403.0			37.0*									
403.0			13.6*			0.7*						
403.2		20.9**	53.5**	0.8*							1.1**	

Station Number	Methoxy-chlor	Ethyl-para-thion	Methyl-para-thion	Oxa-diazon	Phenol	Penta-chloro-phenol	Tetra-chloro-phenol	Total PCB	Tetra-difon	Toxa-phene	Tri-butyl-tin
401.9	0.50**										
402.1										100.0**	
402.2											
402.2											
402.2				1.5*						130.0**	
402.3											
402.5				1.4*						74.0*	
403.0											
403.0											
403.2											

* RCM = Resident California Mussel
RBM = Resident Bay Mussel
TCM = Transplanted California Mussel
TFC = Transplanted Fresh Water Clam
RFC = Resident Fresh Water Clam

* = Equals or exceeds EDL 85.
** = Equals or exceeds EDL 95.
# = Equals or exceeds NAS recommended guideline.
= Equals or exceeds FDA action level.

APPENDIX F (continued)

State Mussel Watch Program

Summary of 1987-93 Data: Organic Chemicals Exceeding Selected Criteria (ppb, wet weight)

Station Number	Station Name	Sample Type*	Sample Date	Aldrin	Chlor-ben-side	Total Chlor-dane	Chlor-pyrifos	Dacthal	Diaz-inon	Total DDT	Di-chloro-benzophenone
403.6	Moro Cojo Slough	TCM	02/02/88					2.0*			
404.0	Sandholdt Bridge	TCM	01/04/89					7.3**		168.3*	
404.0	Sandholdt Bridge	TCM	02/19/90				1.0*	9.9**	10.0**	236.7*	
404.0	Sandholdt Bridge	TCM	02/04/91					0.8*			
404.0	Sandholdt Bridge	TCM	01/28/92				4.0**	20.0**		217.8*	
404.0	Sandholdt Bridge	TCM	02/01/93	0.2**			7.3**	43.0**		393.3**	
405.2	Old Salinas River 2	TFC	03/10/93								
405.3	Old Salinas River 1	TFC	03/10/93				110.0**	300.0*			
405.7	Salinas River Lag 2	TFC	03/16/92							1068.1#	5.4**
406.0	Westley Station	RFC	01/04/89					0.9**			

Station Number	Dicofol	Diel-drin	Total Endo-sulfan	Endrin	Ethion	alpha-HCH	beta-HCH	delta-HCH	Gamma-HCH	Hepta-chlor	Hepta-chlor-epoxide	Hexa-chloro-benzene
403.6			25.4*									
404.0		11.5*	55.7**	1.4**								
404.0		15.0*	72.0**									
404.0												
404.0		30.0**	35.5*	5.9**							0.4*	
404.0		47.0**	46.8*	6.8**	2.1**						0.5**	0.2**
405.2									0.6*			
405.3				20.0*							0.8*	1.4*
405.7			105.4*	20.0*		0.2*						
406.0			1.1*									

Station Number	Methoxy-chlor	Ethyl-para-thion	Methyl-para-thion	Oxa-diazon	Phenol	Penta-chloro-phenol	Tetra-chloro-phenol	Total PCB	Tetra-difon	Toxa-phene	Tri-butyl-tin
403.6											
404.0										26.9*	
404.0										140.0**	
404.0											
404.0										83.0**	
404.0	1.00**			1.2*						350.0**	
405.2											
405.3	1.70**										
405.7	3.50**										
406.0											

* RCM = Resident California Mussel
RBM = Resident Bay Mussel
TCM = Transplanted California Mussel
TFC = Transplanted Fresh Water Clam
RFC = Resident Fresh Water Clam

* = Equals or exceeds EDL 85.
** = Equals or exceeds EDL 95.
# = Equals or exceeds NAS recommended guideline.
= Equals or exceeds FDA action level.

APPENDIX F (continued)

State Mussel Watch Program

Summary of 1987-93 Data: Organic Chemicals Exceeding Selected Criteria (ppb, wet weight)

Station Number	Station Name	Sample Type*	Sample Date	Aldrin	Chlor-ben-side	Total Chlor-dane	Chlor-pyrifos	Dacthal	Diaz-inon	Total DDT	Di-chloro-benzophenone
406.5	Tembladero Slough	TFC	03/10/93	0.8*			110.0**	250.0*			
407.4	Blanco Pump/West	TFC	03/10/93				61.0*				
409.0	Salinas/Reclamation Canal 4	TFC	02/03/88	1.4*		143.2**	288.0**	171.0*		2556.9#	
414.0	Pacific Grove	RCM	12/19/88					0.4*			
414.0	Pacific Grove	RCM	01/09/89								
414.0	Pacific Grove	RCM	02/08/90								
414.0	Pacific Grove	RCM	01/31/92								
414.0	Pacific Grove	RCM	02/12/93					0.2*			
421.7	Monterey Harbor/Marina	TCM	01/22/88								
421.7	Monterey Harbor/Marina	TCM	04/05/89								

Station Number	Dicofol	Diel-drin	Total Endo-sulfan	Endrin	Ethion	alpha-HCH	beta-HCH	delta-HCH	Gamma-HCH	Hepta-chlor	Hepta-chlor-epoxide	Hexa-chloro-benzene
406.5										0.1*	1.4*	1.5*
407.4		150.0*										
409.0		396.0##		37.8**								
414.0			0.9*							0.1**		
414.0			0.9*									
414.0			0.8*									
414.0												
414.0												
421.7												
421.7												

Station Number	Methoxy-chlor	Ethyl-para-thion	Methyl-para-thion	Oxa-diazon	Phenol	Penta-chloro-phenol	Tetra-chloro-phenol	Total PCB	Tetra-difon	Toxa-phene	Tri-butyl-tin
406.5										660.0*	
407.4										770.0*	
409.0								82.8*		3510.0**	
414.0											
414.0											
414.0											
414.0						2.7**					
414.0											
421.7										104.4**	2618.6*
421.7											1760.0*

* RCM = Resident California Mussel
RBM = Resident Bay Mussel
TCM = Transplanted California Mussel

TFC = Transplanted Fresh Water Clam
RFC = Resident Fresh Water Clam

* = Equals or exceeds EDL 85.
** = Equals or exceeds EDL 95.
\# = Equals or exceeds NAS recommended guideline.
\#\# = Equals or exceeds FDA action level.

APPENDIX H (continued)

State Mussel Watch Program

Summary of 1987-93 Data: Substances Exceeding Maximum Tissue Residue Levels (MTRLs) in Enclosed Bays and Estuaries

(ppb, wet weight)

Station Number	Station Name	Sample Type*	Sample Date	Aldrin	Total Chlordane	Total DDT	Dieldrin	Heptachlor Epoxide	alpha-HCH	Total PCB	Total PAH	Toxaphene
321.0	Dumbarton Bridge/Channel Marker 14	TCM	12/16/91		2.9		3.5			41.0	21.3	
323.3	Palo Alto Outfall	TCM	12/29/88		4.3		3.7			14.6		
323.3	Palo Alto Outfall	TCM	02/09/90		9.2		2.9			15.0		
326.0	Palo Alto/Channel Marker 8	TCM	01/16/91		6.7		1.9			17.3	31.4	
326.0	Palo Alto/Channel Marker 8	TCM	12/16/91		3.7		4.3			47.0	38.4	
326.0	Palo Alto/Channel Marker 8	TCM	02/01/93		3.3		1.2			15.0	6.7	
401.3	Moss Landing/Yacht Harbor	TCM	01/04/89		3.5	35.7	14.2			11.4		
402.1	Azevedo Pond	TCM	02/25/93		6.9	138.7	47.0	2.0		13.0		100.0
402.2	Parson's Slough	TCM	03/02/88		2.9		5.4			9.4		
402.2	Parson's Slough	TCM	01/04/89		2.3		3.9			5.7		
402.2	Parson's Slough	TCM	02/25/93		6.9	110.0	24.0			15.0		130.0
402.3	Elkhorn Slough/Pacific Mariculture	TCM	01/04/89		2.4		5.1			5.3		
402.5	Elkhorn Slough/Tidal Pond	TCM	02/25/93		3.1	59.1	20.0	2.2		7.2		74.0
403.0	Elkhorn Slough/Highway 1 Bridge	TCM	03/02/88				2.0					
403.0	Elkhorn Slough/Highway 1 Bridge	TCM	01/04/89		2.8		2.5			4.8		
403.2	Moro Cojo	TCM	01/04/89		8.4	64.9	20.9	1.1		12.0		
403.6	Moro Cojo Slough	TCM	02/02/88		2.8	39.2	4.9			10.0		
404.0	Sandholdt Bridge	RBM	11/05/87		3.7	74.9	2.8			16.8		
404.0	Sandholdt Bridge	RBM	02/02/88		7.8	136.1	3.6			43.4		
404.0	Sandholdt Bridge	RBM	04/07/88		1.9	51.8	4.4			22.8		
404.0	Sandholdt Bridge	RBM	12/08/88		5.9	175.6	5.6			31.5		
404.0	Sandholdt Bridge	TCM	01/04/89		5.1	168.3	11.5			42.2		26.9
404.0	Sandholdt Bridge	TCM	02/19/90		5.5	236.7	15.0			39.0		140.0
404.0	Sandholdt Bridge	TCM	02/04/91		3.8	51.7	2.0			13.3	168.5	
404.0	Sandholdt Bridge	TCM	01/28/92		3.2	217.8	30.0			32.0	154.5	83.0
404.0	Sandholdt Bridge	TCM	02/01/93		14.8	393.3	47.0			38.0	116.5	350.0
421.7	Monterey Harbor/Marina	TCM	01/22/88		9.6		3.4			115.2		104.4
445.0	San Luis Harbor/Transplant	TCM	09/25/87							6.4		
445.0	San Luis Harbor/Transplant	TCM	03/15/88							19.0		
445.0	San Luis Harbor/Transplant	TCM	03/01/89							24.8		
445.0	San Luis Harbor/Transplant	TCM	09/28/89							8.7		
445.0	San Luis Harbor/Transplant	TCM	03/06/90							36.0		
445.0	San Luis Harbor/Transplant	TCM	02/25/91							21.0	1061.6	
445.0	San Luis Harbor/Transplant	TCM	09/09/91							14.0		
445.0	San Luis Harbor/Transplant	TCM	02/25/92							110.0	1879.6	
460.0	Goleta Slough 1	TCM	12/18/88		12.9		1.3			4.1		
475.0	Carpinteria Marsh	TCM	01/26/88		2.9		1.0					
475.0	Carpinteria Marsh	TCM	12/18/88		6.2	35.3	2.0			5.3		
485.0	Ventura Marina	TCM	01/25/88		14.1	104.1	1.4			49.4		
506.1	Port Hueneme/Wharf B	TCM	01/25/88		6.4	93.9	0.9			234.0	2530.0	
506.1	Port Hueneme/Wharf B	TCM	12/18/88							354.9		

* RBM = Resident Bay Mussel   RCM = Resident California Mussel   TCM = Transplanted California Mussel

APPENDIX I (continued)

State Mussel Watch Program

Summary of 1987-93 Data: Trace Elements and Organic Chemicals Exceeding Maximum Tissue Residue Levels (MTRLs) in Inland Surface Waters

(wet weight)

Station Number	Station Name	Sample Type*	Sample Date	Arsenic (ppm)	Cadmium (ppm)	Aldrin (ppb)	Total Chlordane (ppb)	Total DDT (ppb)	Total Endosulfan (ppb)	Dieldrin (ppb)	Heptachlor Epoxide (ppb)	Hexachlorobenzene (ppb)	gamma-HCH (ppb)	Total PCB (ppb)	Total PAH (ppb)	Toxaphene (ppb)
400.8	Aptos Creek	TFC	01/31/90	0.95			6.3							16.8		
400.8	Aptos Creek	TFC	10/25/90	0.80			1.6							8.0		
400.8	Aptos Creek	RFC	11/14/90	1.20										8.2	5.9	
400.8	Aptos Creek	RFC	11/26/90											6.3		
400.8	Aptos Creek	TFC	12/19/91	0.70			1.5									
401.5	Watsonville Slough/Bridge	TFC	02/02/88			1.0	31.4	359.8		75.0	3.0			13.0		460.0
401.5	Watsonville Slough/Bridge	TFC	03/10/93			1.0	49.4	1058.1		170.0	2.6			27.0		1500.0
401.6	Harkins Slough Bridge	TFC	02/02/88				12.6	40.3		2.3	1.0					
401.8	San Andreas Road	TFC	02/03/88			0.7	21.4	437.0		126.0	2.0			16.2		279.0
401.9	Pajaro River Estuary	TFC	03/10/93				9.8	156.4		14.0				15.0		280.0
405.2	Old Salinas River 2	TFC	03/16/92		1.20											
405.2	Old Salinas River 2	TFC	03/10/93				2.5			3.0				15.0		51.0
405.3	Old Salinas River 1	TFC	03/16/92				4.2	520.8		53.0				29.0		260.0
405.3	Old Salinas River 1	TFC	03/10/93			0.6	27.0	450.6		70.0	0.8			51.0		540.0
405.6	Salinas River Lag 1	TFC	03/10/93				3.1	38.0		5.2				20.0		50.0
405.7	Salinas River Lag 2	TFC	03/16/92			0.4	19.3	1068.1		89.0				59.0		250.0
406.0	Westley Station	RFC	01/04/89							1.1				4.2		
406.5	Tembladero Slough	TFC	03/10/93			0.8	22.4	397.8		68.0	1.4			48.0		660.0
407.4	Blanco Pump/West	TFC	03/10/93			0.6	19.9	718.0		150.0				44.0		770.0
408.9	Salinas/Reclamation Canal 3	TFC	02/03/88				30.6	999.2		192.0	6.1			96.0		2480.0
409.0	Salinas/Reclamation Canal 4	TFC	02/03/88			1.4	143.2	2556.9		396.0				82.8		3510.0
425.4	Lake San Antonio/Buoy	TFC	12/08/87		1.43					1.0						
425.6	Lake San Antonio	RFC	10/28/87		1.66					0.8						
425.6	Lake San Antonio	RFC	09/14/88	0.61	0.94											
425.6	Lake San Antonio	RFC	08/15/89		2.48											
425.6	Lake San Antonio	TFC	05/25/92	0.50	0.90		1.2							18.0	38.0	
446.0	San Luis Obispo Creek 1	TFC	02/26/91				17.5							14.1		
480.0	Lake Isabella	RFC	02/09/93	1.90			1.9							13.0	15.9	
507.8	Revolon Slough	TFC	03/14/88				257.2	3845.1	294.0	33.6	28.7	12.6		285.6		3290.0
507.8	Revolon Slough	TFC	01/29/89				89.8	2507.8	1292.8	13.1			2.7	44.4		7474.0
507.8	Revolon Slough	TFC	03/11/91				113.0	983.6		4.4						2822.0
719.1	Santa Ana River/Prado Dam	TFC	04/02/92	0.70			12.6	74.0		5.7				64.0		
719.1	Santa Ana River/Prado Dam	TFC	03/17/93				9.4	69.9		5.1				49.0	191.7	
727.0	Garden Grove/Wintersburg Channel	TFC	01/23/91				13.3			5.3				29.4		
727.0	Garden Grove/Wintersburg Channel	TFC	03/17/93				18.9	95.8		4.4				61.0	210.2	
728.4	Upper Newport Bay/MacArthur	TFC	03/07/88		1.03											
728.4	Upper Newport Bay/MacArthur	TFC	12/20/88		0.80		10.1	185.0		3.1				23.0	30.6	
728.4	Upper Newport Bay/MacArthur	TFC	03/14/90				21.4	141.0		2.4				43.0		120.0
728.4	Upper Newport Bay/MacArthur	TFC	01/23/91		8.40		15.5	88.2		1.6				22.5		
728.4	Upper Newport Bay/MacArthur	TFC	03/17/93				11.1	76.0		2.8				27.0	72.9	110.0

* TFC = Transplanted Fresh Water Clam   RFC = Resident Fresh Water Clam

TABLE 2

Maximum Tissue Residue Levels (MTRLs) in Ocean Waters

Carcinogens [a]

Substance	Water Quality Objective [b] (µg/l)	BCF [c] (l/kg)	MTRL [d] (µg/kg, ppb wet weight)
aldrin	0.000022	e	0.1
chlordane (total)	0.000023	14100	0.32
DDT (total)	0.00017	53600	9.1
dieldrin	0.00004	4670	0.2
heptachlor	0.00072	11200	8.1
hexachlorobenzene (HCB)	0.00021	8690	2.0
PAHs (total)	0.0088	30	0.26
PCBs (total)	0.000019	31200	0.6
toxaphene	0.00021	13100	2.75

a. The SMWP does not analyze for any of the non-carcinogens listed in the human health section of Table B of the 1990 Ocean Plan.

b. From Table B, Objectives for Human Health, "*California Ocean Plan*" (SWRCB 1990a).

c. Bioconcentration Factors taken from the USEPA 1980 Ambient Water Quality Criteria Documents for each substance.

d. MTRLs were calculated by multiplying the Water Quality Objective by the BCF, except for aldrin.

e. Aldrin MTRL is derived from a combination of aldrin and dieldrin risk factors and BCFs as recommended in the USEPA 1980 "*Ambient Water Quality Criteria for Aldrin/Dieldrin*" (USEPA 1980).

TABLE 3

Maximum Tissue Residue Levels (MTRLs) in Enclosed Bays and Estuaries

Carcinogens

Substance	Water Quality Objective [a] (µg/l)	BCF [b] (l/kg)	MTRL [c] (µg/kg, ppb)
aldrin	0.00014	d	0.33
chlordane (total)	0.000081	14100	1.2
DDT (total)	0.0006	53600	32.0
dieldrin	0.00014	4670	0.7
heptachlor	0.00017	11200	1.9
heptachlor epoxide	0.00007	11200	0.8
hexachlorobenzene (HCB)	0.00069	8690	6.0
hexachlorocyclohexane (HCH), alpha	0.0013	130	1.7
hexachlorocyclohexane (HCH), beta	0.046	130	6.0
hexachlorocyclohexane (HCH), gamma	0.062	130	8.1
PAHs (total)	0.031	30	0.93
PCBs (total)	0.00007	31200	2.2
pentachlorophenol (PCP)	8.2	11	90.0
toxaphene	0.00069	13100	9.0

Non-carcinogens

Substance	Water Quality Objective [a] (mg/l)	BCF [b] (l/kg)	MTRL [c] (mg/kg, ppm)
endosulfan (total)	0.002	270	0.5 (500 ppb)
endrin	0.0008	3970	3.2 (3,200 ppb)
mercury	0.000025	e	1.0
nickel	4.6	47	220.0

a. From the *Draft November 26, 1990 Functional Equivalent Document - Development of Water Quality Plans For: Inland Surface Waters of California and Enclosed Bays and Estuaries of California* (SWRCB 1990b), the *Draft April 9, 1991 Supplement to the Functional Equivalent Document* (SWRCB 1991).

b. Bioconcentration Factors taken from the USEPA 1980 Ambient Water Quality Criteria Documents for each substance.

c. MTRLs were calculated by multiplying the Water Quality Objective by the BCF, except for aldrin and mercury.

d. Aldrin MTRL is derived from a combination of aldrin and dieldrin risk factors and BCFs as recommended in the USEPA 1980 "*Ambient Water Quality Criteria for Aldrin/Dieldrin*" (USEPA 1980).

e. The MTRL for mercury is the FDA action level. The water quality objective for mercury in the Enclosed Bays and Estuaries Plan is based on the FDA action level as recommended in the USEPA 1985 "*Ambient Water Quality Criteria for Mercury*" (USEPA 1985).

TABLE 4

Maximum Tissue Residue Levels (MTRLs) in Inland Surface Waters

Carcinogens

Substance	Water Quality Objective [a] (µg/l)	BCF [b] (l/kg)	MTRL [c] (µg/kg, ppb)
aldrin	0.00013	d	0.05
arsenic	5.0 [e]	44	200.0 (0.2 ppm)
chlordane (total)	0.00008	14100	1.1
DDT (total)	0.00059	53600	32.0
dieldrin	0.00014	4670	0.65
heptachlor	0.00016	11200	1.8
heptachlor epoxide	0.00007	11200	0.8
hexachlorobenzene (HCB)	0.00066	8690	6.0
hexachlorocyclohexane (HCH), alpha	0.0039	130	0.5
hexachlorocyclohexane (HCH), beta	0.014	130	1.8
hexachlorocyclohexane (HCH), gamma	0.019	130	2.5
PAHs (total)	0.0028	30	0.08
PCBs (total)	0.00007	31200	2.2
pentachlorophenol (PCP)	0.28	11	3.1
toxaphene	0.00067	13100	8.8

Non-carcinogens

Substance	Water Quality Objective [a] (mg/l)	BCF [b] (l/kg)	MTRL [c] (mg/kg, ppm)
cadmium	0.01	64	0.64
endosulfan (total)	0.0009	270	0.25 (250 ppb)
endrin	0.0008	3970	3.0 (3,000 ppb)
mercury	0.000012	f	1.0
nickel	0.6	47	28.0

a. From the *Draft November 26, 1990 Functional Equivalent Document - Development of Water Quality Plans For: Inland Surface Waters of California and Enclosed Bays and Estuaries of California* (SWRCB 1990b), the *Draft April 9, 1991 Supplement to the Functional Equivalent Document* (SWRCB 1991)

b. Bioconcentration Factors taken from the USEPA 1980 Ambient Water Quality Criteria Documents for each substance.

c. MTRLs were calculated by multiplying the Water Quality Objective by the BCF, except for aldrin, arsenic, and mercury.

d. Aldrin MTRL is derived from a combination of aldrin and dieldrin risk factors and BCFs as recommended in the USEPA 1980 "*Ambient Water Quality Criteria for Aldrin/Dieldrin*" (USEPA 1980).

e. Arsenic MTRL was calculated from the formula NSRL - (WI/BCF) - FC = MTRL. (NSRL (California's No Significant Risk Level for arsenic) = 10 µg/d, WI (Water Intake) = 2 l/d, FC (daily fish consumption) = 0.0065 kg/d).

f. The MTRL for mercury is the FDA action level. The water quality objective for mercury in the Inland Surface Waters Plan is based on the FDA action level as recommended in the USEPA 1985 "*Ambient Water Quality Criteria for Mercury*" (USEPA 1985).

3. ADMINISTRATIVE AND COMPARATIVE CRITERIA

In this report the term "criteria" is used to refer to the criteria against which a particular trace element or organic chemical is being compared. More than one criterion may apply to any one metal or organic compound. In general, FDA action levels, Maximum Tissue Residue Levels (MTRLs), and Median International Standards (MIS), all human health-related criteria, are considered more important or critical. Following human health criteria are NAS guidelines for predator protection and Elevated Data Levels (EDLs). All five criteria are discussed below.

In interpreting the SMWP data by any of the criteria provided, the reader is cautioned that there is no simple relationship between concentrations of toxic substances observed in tissue samples and actual concentrations in water. Different aquatic organisms tend to bioaccumulate a given toxic substance in water to different levels; however, the differences usually do not prevent a general interpretation of the data. The reader is cautioned that the limited number of samples obtained and analyzed at each station in a single year is generally too small to provide a statistically sound basis for making absolute statements on toxic substance concentrations. The values reported herein should be accepted as indicators of relative levels of toxic pollution in water, not as absolute values. In this sense, trends over time and ranking values of a toxic substance provide only an indication of areas where mussels and clams are evidently accumulating concentrations which are above normal.

FDA Action Levels and NAS Guidelines

The FDA has established maximum concentration levels for some toxic substances in human foods (USFDA 1985). The levels are based on specific assumptions of the quantities of food consumed by humans and the frequency of their consumption. The FDA limits are intended to protect humans from the chronic effects of toxic substances consumed in foodstuffs. The National Academy of Sciences (NAS) has established recommended maximum concentrations of toxic substances in animals (NAS 1973). They were established not only to protect the organisms containing the toxic compounds, but also to protect the species that consume these contaminated organisms. The NAS has set guidelines for marine fish but not for marine shellfish. Only two guidelines apply to freshwater clams. The FDA limits and NAS guidelines used in this report are shown in Table 1.

Maximum Tissue Residue Levels (MTRLs)

MTRLs were developed by SWRCB staff from human health water quality objectives in the *1990 California Ocean Plan* (SWRCB 1990a), the *Draft November 26, 1990 Functional Equivalent Document - Development of Water Quality Plans For: Inland Surface Waters of California and Enclosed Bays and Estuaries of California* (SWRCB 1990b), and the *Draft April 9, 1991 Supplement to the Functional Equivalent Document* (SWRCB 1991). The objectives represent concentrations in water that protect against consumption of fish, shellfish, and water (freshwater only) that contain substances at levels which could result in significant human health problems. MTRLs are used as alert levels or guidelines indicating water bodies with potential human health concerns and are an assessment tool and not compliance or enforcement criteria. Tables 2, 3, and 4 lists MTRLs for those substances monitored in the SMWP. The MTRLs for a number of substances listed as carcinogens in the MTRL tables are below the current tissue detection limit for those substances. Detection limits can be found in Tables AA-1, AA-3, and AA-4 in Appendix AA.

The MTRLs were calculated by multiplying the human health water quality objectives in by the bioconcentration factor (BCF) for each substance as recommended in the USEPA *Draft Assessment and Control of Bioconcentratable Contaminants in Surface Waters* (USEPA 1991). BCFs were taken from the USEPA 1980 Ambient Water Quality Criteria Documents for each substance. MTRLs were not calculated for objectives that are based on maximum contaminant levels (MCLs) or taste and odor criteria.

Median International Standards (MIS) for Trace Elements

The MIS is an in-house criterion developed from a Food and Agriculture Organization of the United Nations publication of a survey of health protection criteria used by member nations (Nauen 1983). A description of how the Median International Standards were compiled by SWRCB staff is provided in Appendix BB. These criteria vary somewhat in the tissues to be analyzed or the level of protection desired, but may be compared qualitatively. Table 5 summarizes these standards as an indication of what other countries have determined to be unsafe levels of trace elements. Though the standards do not apply within the United States, they provide an indication of what other nations consider to be an elevated concentration of trace elements in shellfish.

Elevated Data Levels

The "elevated data level" (EDL) was introduced by SWRCB staff in 1983 as an internal comparative measure which ranks a given concentration of a particular substance with previous data from the SMWP. The EDL is calculated by ranking all of the results for a species and exposure condition (resident or transplant) and a given chemical from the highest concentration measured down to and including those records where the chemical was not detected. From this, a cumulative distribution is constructed and percentile rankings are calculated. For example, the 50th percentile corresponds to the median or "middle" value rather than to the mean. With a large number of records, the median can be approximately compared to the mean.

The 85th percentile (EDL 85) was chosen as an indication that a chemical is markedly elevated from the median. The 85th percentile corresponds to measures used by the U.S. Fish and Wildlife Service in its National Contaminant Biomonitoring Program and would represent approximately one and one-half standard deviations from the mean, if the data were normally distributed. The 95th percentile (EDL 95) was chosen to indicate values that are highly elevated above the median. The 95th percentile would represent two standard deviations from the mean, if the data were normally distributed. When used along with other information, these measures provide a useful guideline to determine if a chemical has been found in unusually high concentrations. A more detailed description of EDL rankings is provided in Appendix CC. The reader is cautioned that EDLs are not directly related to potentially adverse human or animal health effects; they are only a way to compare findings in a particular area with the larger data base of findings from all over the state. The 1977-93 EDLs and the number of data points used to calculate each EDL are provided in Tables 6 through 13.

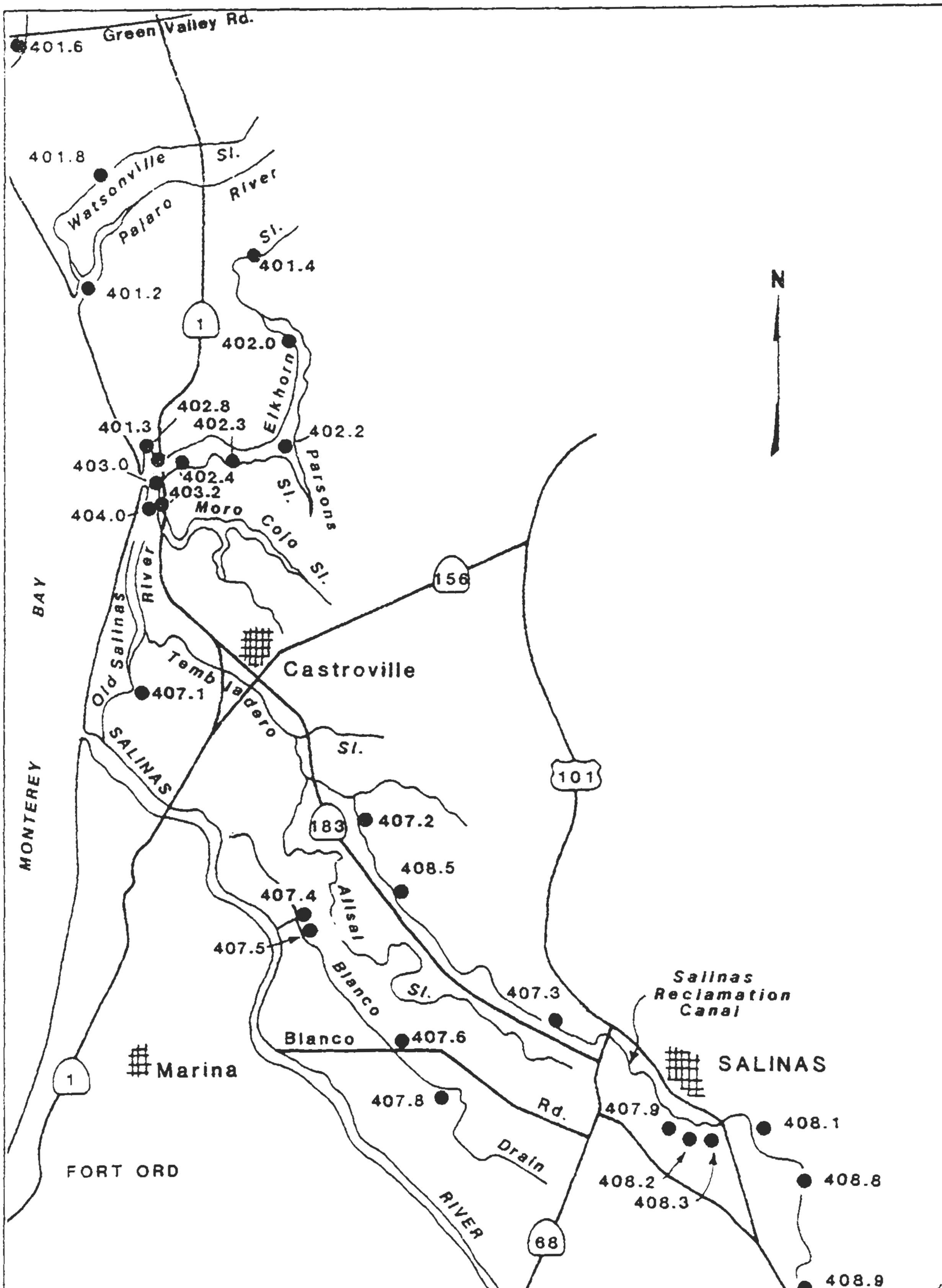
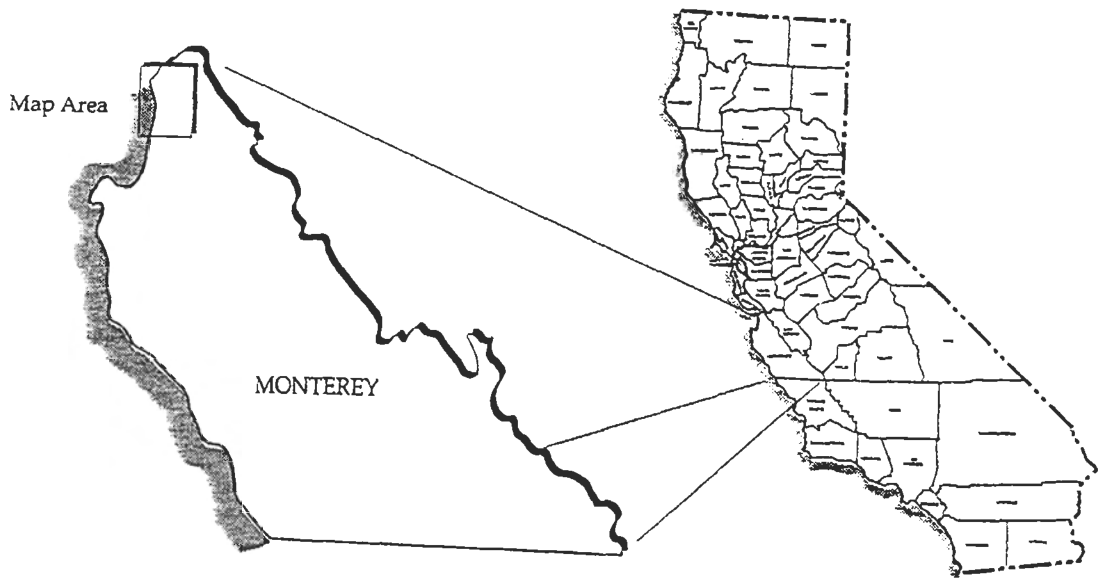
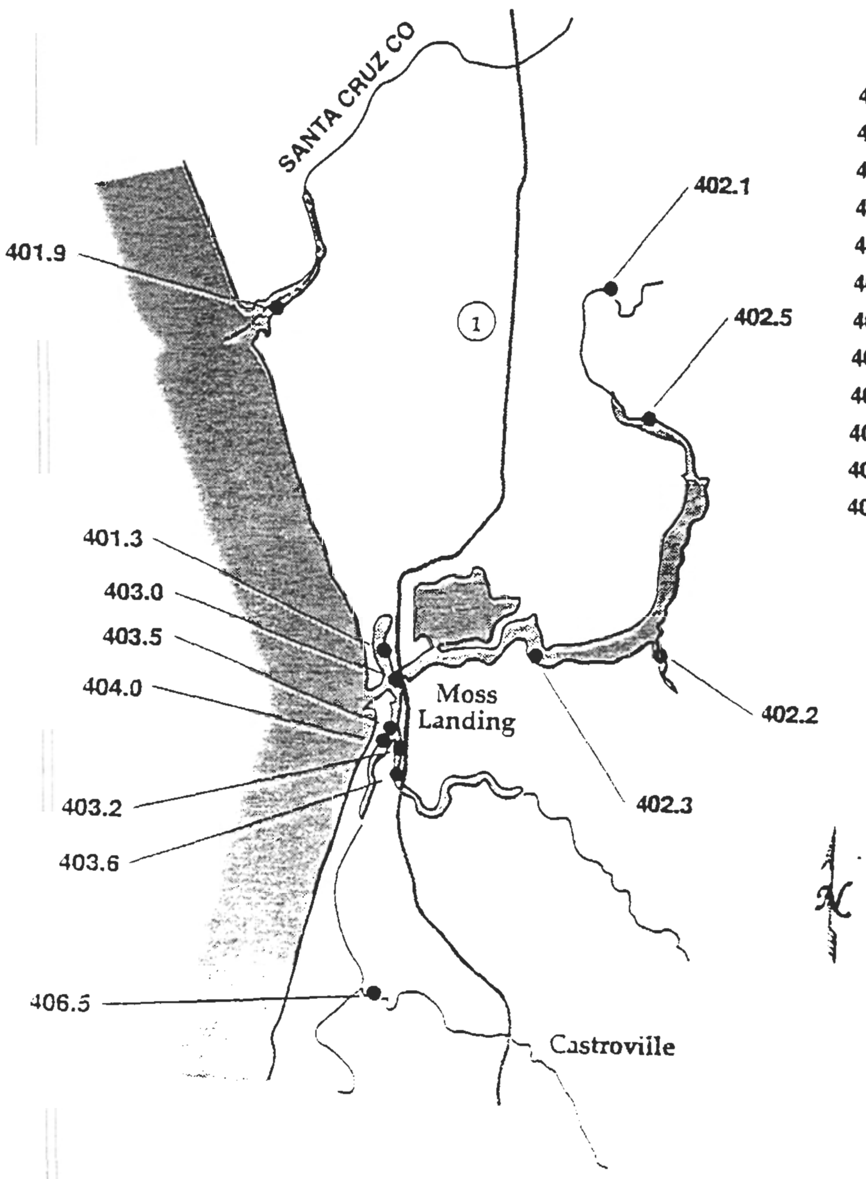


FIGURE C-11 MONTEREY BAY DRAINAGE AREA STATIONS

STATE MUSSEL WATCH 1987-93 SAMPLING STATIONS

Monterey Co. - Moss Landing Area

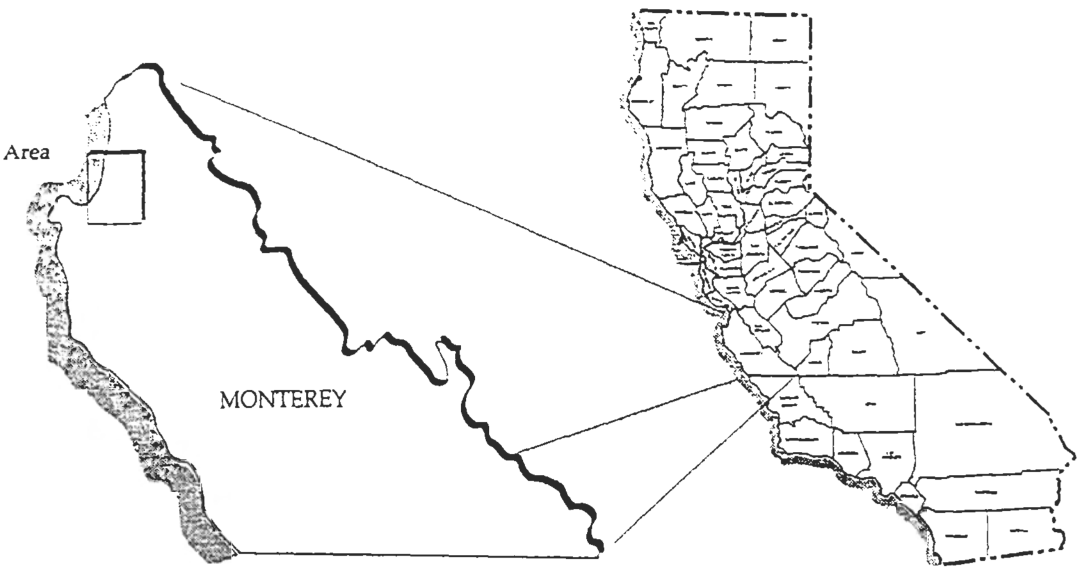


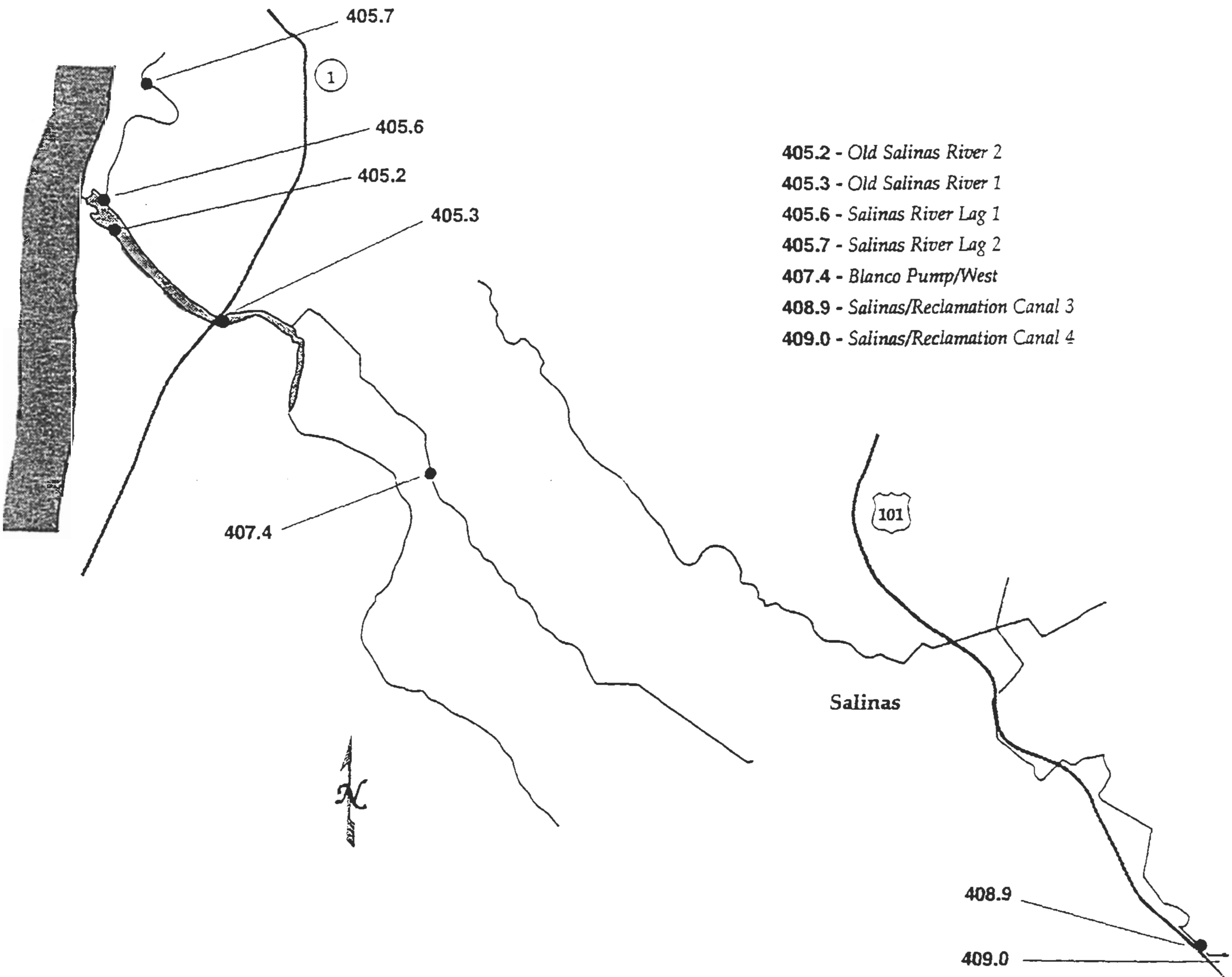


401.3 - *Moss Landing/Yacht Harbor*
401.9 - *Pajaro River Estuary*
402.1 - *Azevedo Pond*
402.2 - *Parson's Slough*
402.3 - *Elkhorn Slough/Pacific Mariculture*
402.5 - *Elkhorn Slough/Tidal Pond*
403.0 - *Elkhorn Slough/Highway 1 Bridge*
403.2 - *Moro Cojo*
403.5 - *Moss Landing/South Harbor*
403.6 - *Moro Cojo Slough*
404.0 - *Sandholdt Bridge*
406.5 - *Tembladero Slough*

STATE MUSSEL WATCH 1987-93 SAMPLING STATIONS

Monterey Co. - Salinas Area





Toxic Substances Monitoring Program 1978-1993

TABLE 17

Toxic Substances Monitoring Program

Organic Chemicals Exceeding Selected Criteria in **Region 3**: Ten Year Data Summary (1978-87)

(ppb, wet weight)

STATION NUMBER	STATION NAME	SPECIES CODE	TISSUE	SAMPLE DATE	Total Chlordane (N/F)	Chlor-Pyrifos (EDL)	Dacthal (EDL)	Total DDT (N/F)	Dieldrin (N/F)	Total Endosulfan (N)
305.10.02	WATSONVILLE SL/SAN ANDREAS RD	STB	W	06/15/84	278.7#			10020.0#	1700.0#	242.0#
305.10.02	WATSONVILLE SL/SAN ANDREAS RD	STB	W	06/05/85	195.8#			6664.0#	960.0#	261.0#
305.10.03	PAJARO R/D/S HWY 1 BRG	BB	F	07/13/82			24.0*			
305.10.04	HARKINS SL/U/S WATSONVILLE SL	CP	F	06/05/85	208.0#			2623.0#	240.0#	252.0#
305.10.04	HARKINS SL/U/S WATSONVILLE SL	SBF	F	06/05/85				1098.0#		
305.10.05	WATSONVILLE SL/U/S HARKINS SL	CP	W	06/05/85				3815.0#	460.0#	
305.10.05	WATSONVILLE SL/U/S HARKINS SL	GAM	W	06/05/85				4468.0#	810.0#	
305.10.06	WATSONVILLE SL/HARKINS SL RD	STB	W	10/02/86	287.5#					
309.10.00	SALINAS R LAGOON	SKR	F	08/24/83			19.0*			
309.10.02	LOWER TEMBLADERO SL	SKR	F	08/23/83			320.0**			

STATION NUMBER	Endrin (N/F)	alpha-HCH (EDL)	gamma-HCH (Lindane) (N)	Total HCH (N)	Heptachlor Epoxide (N/F)	Hexachloro-benzene (EDL)	Methoxy-chlor (EDL)	Penta-chloro-phenol (EDL)	Tetra-chloro-phenol (EDL)	Total PCB (N/F)	Toxaphene (N/F)	Chemical Group A (N)
305.10.02		2.1*									12000.0#	14287.8#
305.10.02											2300.0#	3730.0#
305.10.03												
305.10.04						2.7*					710.0#	1466.0#
305.10.04												120.0#
305.10.05											1500.0#	2101.6#
305.10.05											510.0#	1403.0#
305.10.06										676.0#		335.8#
309.10.00												
309.10.02												

* = Exceeds the EDL 85. ** = Exceeds the EDL 95. # = Equals or exceeds NAS recommended guideline. ## = Equals or exceeds FDA action level.
EDL means that the results were compared to EDL 85 and EDL 95 values. N means that the results were compared to NAS criteria only.
N/F means that the results were compared to NAS and FDA criteria.
F = Filet. W = Whole Body.

TABLE 17 (continued)

Toxic Substances Monitoring Program

Organic Chemicals Exceeding Selected Criteria In Region 3: Ten Year Data Summary (1978-87)

(ppb, wet weight)

STATION NUMBER	STATION NAME	SPECIES CODE	TISSUE	SAMPLE DATE	Total Chlordane (N/F)	Chlor-Pyrifos (EDL)	Dacthal (EDL)	Total DDT (N/F)	Dieldrin (N/F)	Total Endosulfan (N)
309.10.02	LOWER TEMBLADERO SL	SBF	F	06/13/84			82.0*			
309.10.02	LOWER TEMBLADERO SL	SBF	F	06/13/84			100.0*			
309.10.04	OLD SALINAS R/MONTEREY DUNES BRG	STB	W	08/24/83	151.0#		830.0**	2504.0#	350.0#	841.0#
309.10.05	SALINAS R/BLANCO DRAIN	SKR	F	08/24/83			43.0*	1877.0#		
309.10.05	SALINAS R/BLANCO DRAIN	SKR	F	06/12/84						
309.10.05	SALINAS R/BLANCO DRAIN	SKR	F	06/12/84						
309.10.07	SALINAS R/BLANCO RD	SKR	F	08/25/83			37.0*			
309.10.08	ESPINOSA SLOUGH	SBF	F	06/15/84			310.0**			
309.10.09	BLANCO DRAIN/SALINAS R	SKR	F	06/12/84						
309.10.09	BLANCO DRAIN/SALINAS R	SKR	F	06/12/84						

STATION NUMBER	Endrin (N/F)	alpha-HCH (EDL)	gamma-HCH (Lindane) (N)	Total HCH (N)	Heptachlor Epoxide (N/F)	Hexachloro-benzene (EDL)	Methoxy-chlor (EDL)	Penta-chloro-phenol (EDL)	Tetra-chloro-phenol (EDL)	Total PCB (N/F)	Toxaphene (N/F)	Chemical Group A (N)
309.10.02											450.0#	522.6#
309.10.02											400.0#	499.2#
309.10.04	120.0#	2.2**				11.0*					2200.0#	3675.2#
309.10.05						3.1*					870.0#	931.0#
309.10.05											470.0#	526.0#
309.10.05											570.0#	639.0#
309.10.07						2.5*						
309.10.08						3.2*					520.0#	638.5#
309.10.09											630.0#	720.0#
309.10.09											740.0#	833.0#

* = Exceeds the EDL 85. ** = Exceeds the EDL 95. # = Equals or exceeds NAS recommended guideline. ## = Equals or exceeds FDA action level.

EDL means that the results were compared to EDL 85 and EDL 95 values. N means that the results were compared to NAS criteria only.

N/F means that the results were compared to NAS and FDA criteria.

F = Filet. W = Whole Body.

TABLE 17 (continued)

Toxic Substances Monitoring Program

Organic Chemicals Exceeding Selected Criteria in **Region 3**: Ten Year Data Summary (1978-87)

(ppb, wet weight)

STATION NUMBER	STATION NAME	SPECIES CODE	TISSUE	SAMPLE DATE	Total Chlordane (N/F)	Chlor-Pyrifos (EDL)	Dacthal (EDL)	Total DDT (N/F)	Dieldrin (N/F)	Total Endosulfan (N)
309.10.13	SALINAS REC CANAL/DAVIS RD	SBF	F	06/14/84			380.0**	1240.0#	110.0#	
309.10.13	SALINAS REC CANAL/DAVIS RD	HCH	W	06/04/85	188.7#		360.0*	8900.0#	320.0#	
309.10.13	SALINAS REC CANAL/DAVIS RD	GF	W	10/01/86	101.0#	76.0*	320.0*	2473.0#	490.0#	165.0#
309.10.13	SALINAS REC CANAL/DAVIS RD	HCH	W	08/11/87		72.0*	1200.0**	3068.0#	380.0#	
309.10.15	BLANCO DRAIN/HITCHCOCK RD	HCH	F	06/06/85			26.0*	2395.0#	110.0#	245.0#
309.10.15	BLANCO DRAIN/HITCHCOCK RD	SQF	F	06/06/85			48.0*	17558.0##	550.0##	840.0#
309.10.17	SALINAS REC CANAL/AIRPORT RD	GF	W	10/01/86				4067.0#	220.0#	180.0#
309.10.17	SALINAS REC CANAL/AIRPORT RD	GF	W	08/13/87		230.0**	1000.0**	4046.0#	490.0#	161.0#
309.10.18	SALINAS R/MOUTH	SKR	F	07/14/82			15.0*			
315.34.00	CARPINTERIA MARSH	LJM	W	08/02/83						

STATION NUMBER	Endrin (N/F)	alpha-HCH (EDL)	gamma-HCH (Lindane) (N)	Total HCH (N)	Heptachlor Epoxide (N/F)	Hexachloro-benzene (EDL)	Methoxy-chlor (EDL)	Penta-chloro-phenol (EDL)	Tetra-chloro-phenol (EDL)	Total PCB (N/F)	Toxaphene (N/F)	Chemical Group A (N)
309.10.13						2.9*					880.0#	1031.8#
309.10.13						9.2*				840.0#	6800.0#	7382.1#
309.10.13						16.0*					1100.0#	1931.0#
309.10.13						20.0**					1100.0#	1703.8#
309.10.15											270.0#	625.0#
309.10.15										1260.0#	1800.0#	3320.0#
309.10.17											1100.0#	1582.9#
309.10.17						11.0*	18.0**				1300.0#	2074.4#
309.10.18												
315.34.00											670.0#	680.0#

* = Exceeds the EDL 85. ** = Exceeds the EDL 95. # = Equals or exceeds NAS recommended guideline. ## = Equals or exceeds FDA action level.

EDL means that the results were compared to EDL 85 and EDL 95 values. N means that the results were compared to NAS criteria only.

N/F means that the results were compared to NAS and FDA criteria.

F = Filet. W = Whole Body.

APPENDIX F

Toxic Substances Monitoring Program

Summary of 1991 Data: Organic Chemicals in Freshwater Fish Exceeding Selected Criteria

(ppb, wet weight)

Station Number	Station Name	Species Code	Tissue	Sample Date	Total Chlordane (N/F)	Chlor-pyrifos (EDL)	Dacthal (EDL)	Total DDT (N/F)
304.12.91	Neary's Lake	SSKR	F	08/06/91	123.0#			
309.10.09	Blanco Drain/Salinas R	STB	W	09/04/91	168.0#			13019.0#
309.10.09	Blanco Drain/Salinas R	STB	W	09/04/91	152.0#			12299.0#
403.11.02	Rio de Santa Clara/Oxnard Drain	GAM	W	06/17/91	333.8#			5744.0#
403.12.06	Calleguas Creek	GF	F	06/18/91			30.0*	1170.0#
403.12.07	Conejo Creek	GAM	W	06/19/91			120.0*	2422.0#
404.23.04	Lindero Lake	LMB	F	04/22/91				
405.12.90	Harbor Park Lake	CP	F	06/15/91	370.4##			
405.15.97	Belvedere Park Lake	FHM	W	04/18/91	151.1#			
405.15.97	Belvedere Park Lake	FHM	W	04/18/91	161.7#			

Station Number	Diazinon (EDL)	Dieldrin (N/F)	Total Endosulfan (N/F)	Hexa-chloro-benzene (EDL)	Oxadiazon (EDL)	Total PCB (N/F)	Toxaphene (N/F)	Chemical Group A (N)
304.12.91								123.0#
309.10.09		1000.0#				850.0#	6000.0#	7242.0#
309.10.09	120.0**	1100.0#				1010.0#	4000.0#	5318.0#
403.11.02						858.0#	1200.0#	1695.8#
403.12.06							440.0#	445.9#
403.12.07			210.0#				2000.0#	2306.9#
404.23.04					17.0**			
405.12.90					36.0**	600.0#		385.4#
405.15.97								177.1#
405.15.97								189.7#

* = Equals or exceeds the EDL 85. ** = Equals or exceeds the EDL 95. # = Equals or exceeds NAS recommended guideline.
= Equals or exceeds FDA action level. (EDL) means that the results were compared to EDL 85 and EDL 95 values.
(N) means that the results were compared to NAS criteria only. (N/F) means that the results were compared to NAS and FDA criteria.
F = Filet. W = Whole Body. Species codes are listed in Table 2.

APPENDIX J

Toxic Substances Monitoring Program

Summary of 1992-93 Data: Organic Chemicals in Freshwater Fish Exceeding Selected Criteria

(ppb, wet weight)

Station Number	Station Name	Species Code	Tissue	Sample Date	Total Chlordane (N/F)	Chlor-pyrifos (EDL)	Dacthal (EDL)	Total DDT (N/F)
309.10.05	Salinas R/Blanco Drain	HCH	W	08/11/92		61.0*	750.0**	1520.0#
310.32.01	Oso Flaco Lake	BG	F	08/12/93			19.0*	
310.32.01	Oso Flaco Lake	BG	F	08/12/93			24.0*	
403.11.03	Oxnard Drainage Ditch 2	GF	F	06/23/93	345.0##		160.0*	6771.0##
403.11.04	Revolon Slough	GF	F	06/02/92			120.0*	
403.11.04	Revolon Slough	FHM	W	06/20/93	130.0#	100.0**	900.0**	3222.0#
403.12.06	Calleguas Creek	FHM	W	06/02/92				1784.0#
403.12.06	Calleguas Creek	FHM	W	06/20/93	109.6#			2385.0#
403.12.07	Conejo Creek	FHM	W	06/02/92				1778.0#
403.12.07	Conejo Creek	FHM	W	06/02/92				1391.0#

Station Number	Diazinon (EDL)	Dieldrin (N/F)	Total Endosulfan (N/F)	Hexa-chloro-benzene (EDL)	Oxadiazon (EDL)	Total PCB (N/F)	Toxaphene (N/F)	Chemical Group A (N)
309.10.05							330.0#	416.0#
310.32.01								
310.32.01								
403.11.03							3200.0#	3545.0#
403.11.04							660.0#	695.9#
403.11.04				4.8*			3500.0#	3663.3#
403.12.06							1800.0#	1910.1#
403.12.06							2300.0#	2427.2#
403.12.07							2200.0#	2322.2#
403.12.07							1700.0#	1800.0#

* = Equals or exceeds the EDL 85. ** = Equals or exceeds the EDL 95. # = Equals or exceeds NAS recommended guideline.
= Equals or exceeds FDA action level. (EDL) means that the results were compared to EDL 85 and EDL 95 values.
(N) means that the results were compared to NAS criteria only. (N/F) means that the results were compared to NAS and FDA criteria.
F = Filet. W = Whole Body. Species codes are listed in Tables 3, 4, and 5.

TABLE 3

Guidelines and Action Levels for Toxic Chemicals in Fish
(wet weight)

	NAS[a] Recommended Guideline		FDA[b] Action Level	
	(Whole Fish)		(Edible Portion)	
Chemical	ug/g (ppm)	ng/g (ppb)	ug/g (ppm)	ng/g (ppb)
Mercury	0.5	500	1.0[d]	1,000
DDT (total)	1.0	1,000	5.0	5,000
PCB (total)	0.5	500	2.0[e]	2,000
aldrin	0.1[c]	100	0.3	300
dieldrin	0.1[c]	100	0.3	300
endrin	0.1[c]	100	0.3	300
heptachlor	0.1[c]	100	0.3	300
heptachlor epoxide	0.1[c]	100	0.3	300
chlordane (total)	0.1[c]	100	0.3	300
lindane	0.1	100	-	-
hexachlorocyclo-hexane (total)	0.1[c]	100	-	-
endosulfan (total)	0.1[c]	100	-	-
toxaphene	0.1[c]	100	5.0	5,000

a National Academy of Sciences-National Academy of Engineering, 1973. Water Quality Criteria, 1972 (Blue Book). U.S. Environmental Protection Agency, Ecological Research Series.

b U. S. Food and Drug Administration. 1984. Shellfish Sanitation Interpretation: Action Levels for Chemical and Poisonous Substances, June 21, 1984. U.S.F.D.A., Shellfish Sanitation Branch, Washington, D.C.

c Individually or in combination. Chemicals in this group under NAS Guidelines are referred to as Chemical Group A in this report.

d As methyl mercury.

e A tolerance, rather than an action level, has been established for PCBs (21CFR 109, published May 29, 1984). An action level is revoked when a regulation establishes a tolerance for the same substance and use.

Chapter 3

ADMINISTRATIVE AND COMPARATIVE CRITERIA

In this report, as in previous annual reports, the terms "selected criteria" or "criteria" are used to refer to the criteria against which a particular metal or organic chemical is being compared. As more than one criteria may apply to any one metal or organic compound, a hierarchy was established. The intent of the hierarchy is to compare data against the more important criteria. In general, human health-related criteria such as the FDA action levels and the "Median International Standards" (MIS) are considered more important or critical. Following human health criteria are predator protection criteria, such as the NAS guidelines. Last in the hierarchy is "elevated data levels" (EDL). The following is a description of the above mentioned criteria.

FDA Action Levels and NAS Guidelines

The U.S. Food and Drug Administration (FDA) has established maximum concentration levels for some toxic substances in human foods (USFDA, 1985). The levels are based on specific assumptions of the quantities of food consumed by humans and upon the frequency of their consumption. The FDA limits are intended to protect humans from the chronic effects of toxic substances consumed in foodstuffs. The National Academy of Sciences (NAS) has established recommended maximum concentrations of toxic substance concentrations in fish tissue (NAS, 1973). They were established not only to protect the organisms containing the toxic compounds, but also to protect the species that consume these contaminated organisms. The specific action levels and guidelines used in this report are shown in Table 3.

Median International Standards (MIS) for Trace Elements

The Food and Agriculture Organization of the United Nations has published a survey of health protection criteria used by member nations (Nauen, 1983). These criteria vary somewhat in the tissues to be analyzed or the level of protection desired, but may be compared qualitatively. Table 4 summarizes these standards as an indication of what other countries have determined to be unsafe levels of trace elements. Though the standards do not apply within the United States, they provide an indication of what other nations consider to be an elevated concentration of trace elements in fish tissues. Even so, the reader is reminded that most TSMP metal analyses are done in liver, rather than in edible portions. To date, only mercury and selenium are routinely measured in edible portions in the TSMP. Measurements in liver should not be compared to Median International Standards. A description of how the Median International Standards were compiled is provided in Appendix I.

Elevated Data Levels

The "elevated data level" (EDL) was introduced in 1983 as an internal comparative measure which ranks a given concentration of a particular substance with previous data from the TSMP. The EDL is calculated by ranking all of the results for a given chemical from the highest concentration measured down to and including those records where the chemical was not detected. From this, a cumulative distribution is constructed and percentile rankings are calculated. For example, the 50th percentile corresponds to the median or "middle" value rather than to the mean. With a large number of records, the median can be approximately compared to the mean. The 1978-1987 EDLs and the number of data points used to calculate each EDL are provided in Tables 5, 6, 7, 8, 9 and 10.

In calculating the EDLs for wet weight measures, similar tissue types, such as filets or whole-body samples, are compared only to other samples with the same tissue type (filets are compared only to other filets, etc.). Therefore, a different EDL distribution is calculated for each tissue type. When any sample is compared to an EDL, it is compared to the EDL calculated from the same tissue type. Because trout are known to accumulate copper to higher levels than other species, a separate copper EDL is calculated for salmonid liver tissue. In calculating the EDLs for lipid weight measures of organic chemicals, all tissue types are combined because lipid weight measures in different tissue types tend to be far more similar than do wet weight measures (Phillips, 1980). In this report, the formula used to calculate EDLs was refined which resulted in slightly lower EDL values than those reported in the 1987 annual TSMP report. No significant changes occurred because of this refinement.

The 85th percentile (EDL 85) was chosen as an indication that a chemical is elevated from the median. The 85th percentile corresponds to measures used by the U.S. Fish and Wildlife Service in their National Contaminant Biomonitoring Program and would represent approximately one and one-half standard deviations from the mean, if the data were normally distributed. The 95th percentile (EDL 95) was chosen to indicate values that are highly elevated above the median. The 95th percentile would represent two standard deviations from the mean, if the data were normally distributed. When used along with other information, these measures provide a useful guideline to determine if a chemical has been found in unusually high concentrations. A detailed description of these EDL rankings is provided in Appendix J. The reader is again cautioned that EDLs are not directly related to potentially adverse human or animal health effects; they are only a way to compare findings in a particular area with the larger data base of findings from all over the state.

the mercury found in the Guadalupe River area is thought to be mine tailings from the Almaden Quicksilver Park, which has the nation's oldest mercury mine. Mine wastes are also thought to be the source of mercury in Lake Herman. Besides mercury, the trace element that most often exceeded criteria in Region 2 was arsenic. Nine samples contained relatively high levels of arsenic. The highest arsenic concentrations in the Region were found in 1986 and 1987 in fish from Suisun Bay. Fish from the Bay also contained some of the highest levels of copper, nickel, silver, and zinc detected in Region 2. Levels of cadmium, chromium, lead, mercury, and selenium, however, were found in relatively low concentrations in Suisun Bay. Metals, in general, are a known pollution problem in the San Francisco Bay-Delta system. The highest lead concentration found statewide (1.1 ppm) was detected in 1986 in threespine stickleback from San Leandro Creek at the Highway 17 Bridge.

Pesticide and PCB bioaccumulation do not seem to be major problems in Region 2. Tissue samples with levels above criteria were found at five of the 12 stations analyzed for organic chemicals. Only seven of the 37 samples analyzed in the Region exceeded criteria (Table 15). The rest contained relatively small amounts of organic chemicals. No sample exceeded any FDA action level. Only chlordane and PCB were found above the NAS guidelines. The 652 ppb chlordane detected in a 1986 stickleback sample from San Leandro Creek was the fourth highest chlordane concentration found statewide. Only goldfish from Harbor Park Lake in Region 4 contained higher levels of chlordane. Statewide, chlordane was detected in 45% of the samples analyzed. In Region 2, chlordane was found in 66% of the samples. Only Region 4, another highly urbanized area, had a higher rate of detection (85%). Chlordane had been used for termite control until 1988, when it was banned by the EPA. On a lipid weight basis, a number of samples exceeded criteria even though the wet weight levels in the same samples did not exceed criteria. Chlordane and PCBs account for most of the high lipid weight values.

Region 3

Tissue samples were analyzed from 47 stations on 26 waterbodies in Region 3 (Figure 5). In addition, 13 sediment and soil samples were analyzed from 12 stations (Appendix N). Only Region 5 had more sampling stations from 1978 to 1987. Metal and organic chemical analysis were performed on a total of 182 samples. A mercury survey was conducted at Lake Nacimiento in 1982 and 1983 where 56 individual fish samples were analyzed. The most common of 28 species collected in Region 3 was largemouth bass. Clams and crayfish were also sampled along with two marine species, bocaccio and kelp rockfish, from Moss Landing Harbor and Monterey Harbor, respectively. Both metals and pesticides were found in high concentrations in Region 3. Areas with identified problems include Lakes Nacimiento and San Antonio (metals) and the Watsonville-Salinas area (pesticides).

Elevated metal levels were particularly widespread in Region 3, occurring at 25 of the 32 stations sampled for metals (Table 16). A total of 84 samples, half of which were from Lake Nacimiento, exceeded at least one metal criteria. Thirty-two percent of the 1982-83 mercury survey samples from Lake Nacimiento exceeded the FDA action level of 1.0 ppm, while another 39% exceeded the MIS of 0.5 ppm. Additional samples collected from the Lake in 1984 and 1985 also contained high mercury concentrations. Based on these results, DHS issued a fish consumption health advisory for Lake Nacimiento. Lake Hernandez, in the northeastern part of Region 3, was the only other waterbody to contain high levels of mercury. Like Region 2, the source of the high mercury levels in the Region 3 is thought to be from natural cinnabar deposits and the associated mining activity. Besides mercury, samples from Lake Nacimiento also contained elevated levels of arsenic, copper, silver, and zinc. All four metals are associated with mine waste. The three highest concentrations of copper and the second highest concentration of silver found statewide were detected in the white bass from the Lake. Other species analyzed from Lake Nacimiento had considerably lower levels of both copper and silver. White bass, like trout, may be particularly sensitive to copper as well as other metals. Cadmium was found at elevated levels in eight waterbodies in Region 3. The highest concentrations were detected at Lake San Antonio. Largemouth and smallmouth bass from this Lake had six of the ten highest concentrations of cadmium, including the three highest, found statewide. The State Mussel Watch Program (SMWP), the marine version of the TSMP, has also found elevated levels of cadmium in clams from Lake San Antonio (SWRCB, 1988). There is some evidence that freshwater species can vary widely in their sensitivity to cadmium (USEPA, 1985a). Chorro Creek, near San Luis Obispo, is another waterbody with metal bioaccumulation problems. High levels of chromium, copper, nickel, and zinc were found there in 1986. Chromium levels in almost all other samples in Region 3 were near or below the detection limit. Sources of chromium include mine drainage, agricultural runoff, and industrial discharge.

Pesticide and PCB monitoring in Region 3 was concentrated in the Watsonville-Salinas area. This area is well known for its agricultural products. Not surprisingly, the Watsonville-Salinas area has some of the highest tissue concentrations of agricultural pesticides found statewide. All but one of the 17 stations in Region 3 exceeding pesticide criteria are from this area (Table 17). DDT, diazinon, dieldrin, endosulfan, endrin, and heptachlor epoxide were all found in Region 3 at the highest levels measured in the state. Many of the pesticides detected in Region 3 consistently exceeded criteria. Four substances-dacthal, dieldrin, endosulfan, and toxaphene-were detected nearly twice as often in Region 3 as the statewide average for those substances. No other region had a higher detection rate for dieldrin and toxaphene. Only Region 7 had a higher detection rate for dacthal and endosulfan. Although high levels of many pesticides were found in Region 3, only one waterbody had levels exceeding FDA action levels. Fish from Blanco Drain collected in 1985 contained levels of DDT and dieldrin above FDA action levels. Dacthal is the only pesticide found in Region 3 at high concentrations that is not banned or severely restricted. Currently, dacthal is being reevaluated by the California Department of Food and Agriculture. Methoxychlor, an insecticide, was detected for the first time in 1987 in Regions 3 and 8. In Region 3, methoxychlor was found in one sample from the Salinas Reclamation Canal. Even though most of the pesticides of concern in Region 3 are not now being used, concentrations will continue to remain high because of their persistence in the environment.

Region 4

Region 4 was first sampled in 1981 at a single site on the Santa Clara River. Since then, 16 stations, representing the same number of waterbodies, have been sampled (Figure 6). A total of 48 samples were analyzed in Region 4 representing 14 fish species and one sediment sample (Appendix N). Goldfish was the most common species collected in the Region. Much of the sampling in Region 4 was conducted along the coast, particularly in the agricultural area of Revolon Slough/Calleguas Creek.

Somewhat surprisingly, mercury and selenium concentrations in Suisun Bay continue to be detected at relatively low concentrations. Both elements have been identified as bioaccumulation problems in the Bay-Delta. A fish consumption health advisory for mercury in striped bass has been in effect for many years in the Bay-Delta. Another unusual finding is the lack of pesticide residues in fish from Suisun Bay. Fish from both major tributaries to Suisun Bay, the Sacramento and San Joaquin Rivers, contain a number of pesticides, some at very high levels. Striped bass and white sturgeon form the Bay contained only small amounts of chlordane, DDT, and PCBs. In 1988 samples, dacthal and dieldrin were also detected at levels near the detection limit. Similar pesticide results were found in limited 1989-90 mussel sampling in Suisun Bay through the State Board's Mussel Watch Program (SWRCB 1990b). These findings indicate bioaccumulation of pesticides and PCBs may not be a significant problem in the Bay.

Bear Gulch Reservoir, Lake Chabot, and Vasona Lake, sampled as part of the Lake Assessment Survey, all exceeded metal or organic chemical criteria. The 2.0 ppm selenium found in largemouth bass from Bear Gulch Reservoir is the first time selenium has been detected in Region 2 equaling or exceeding the MIS. The source of the selenium is unknown. The 53 ppb HCB in white catfish from Lake Chabot is the highest concentration of this substance detected in Region 2 and is also the highest concentration detected in 1988-89. The previous high HCB concentration was 8.5 ppb in a 1987 whole stickleback sample from Calabazas Creek. The NAS guideline for Chemical Group A was exceeded at Lake Chabot without an individual pesticide exceeding the guideline. Chlordane made up most of the Chemical Group A total. Dieldrin and HCH were the other pesticides detected. Oxadiazon, detected for the first time in 1989, was found at nine stations statewide including Lake Chabot and Coyote Creek in Region 2. Oxadiazon is a contact herbicide for both grasses and broad-leaved species (see Chemical Assessments - Chapter 5). The 680 ppb PCBs detected in largemouth bass from Vasona Lake is only the third time the NAS guideline for PCBs has been exceeded in Region 2. The two other times were in 1983 and 1984 samples from the Montague Expressway station on Coyote Creek.

Region 3

Region 3 was sampled at 14 stations in 1988 and 11 stations in 1989 (Figure 3). Goleta Slough West, Lake San Antonio, Monterey Harbor, and Moss Landing Harbor were sampled both years. Twelve new stations were sampled in the Region (Tables 1 and 2). Four of these new stations were sampled as part of the 1988 304(l) Survey and two were sampled as part of the 1989 Lake Assessment Survey. A total of 29 samples from Region 3 were analyzed including 13 fish species and one crayfish species. Pacific staghorn sculpin and threespine stickleback dominated the collection accounting for 12 of the 28 fish samples. Topsmelt from Mission Creek and blue rockfish from Monterey Harbor were collected for the first time. Sixteen of the 21 stations sampled in Region 3 exceeded at least one metal or organic chemical criteria, including all four 304(l) Survey stations (Table 15). No criteria were exceeded at the two Lake Assessment Survey stations, James Lake and Whale Rock Reservoir. Organic chemical criteria were not exceeded in the Region in 1989. The highest 1988-89 statewide concentrations of dieldrin and endosulfan were found in Region 3. A regionwide high concentration of arsenic was detected at Monterey Harbor.

Four stations were sampled in the lower Salinas Valley in 1988: two stations at Alisal Slough, Espinosa Slough, and the Salinas Reclamation Canal. All but Espinosa Slough were part of the 304(l) Survey. Espinosa Slough was also the only station out of the four sampled prior to 1988. Fish from the lower Salinas Valley have frequently exceeded criteria for pesticides. The highest statewide concentrations of endosulfan continued to be found in the Valley. The 687 ppb endosulfan found in a whole sample of stickleback from Espinosa Slough is the highest concentration detected in 1988-89. Sacramento blackfish collected from Espinosa Slough in 1984 exceeded the NAS guideline for dacthal and toxaphene. DDT, dieldrin, and endosulfan, which exceeded the NAS guideline in 1988, were found in low concentrations or, in the case of endosulfan, not detected in the 1984 blackfish sample. Results from the Salinas Reclamation Canal station upstream of Tembladero Slough were much the same as results from the upstream Airport Road and Davis Road stations on the canal sampled in past years. Fish from the Salinas Reclamation Canal consistently exceeded criteria for dacthal, DDT, dieldrin, endosulfan, and toxaphene. Espinosa Slough and the Salinas Reclamation Canal are listed in the 1990 WQA as having impaired water quality (SWRCB 1990a).

The Harkins Slough-Watsonville Slough area has been sampled every year since 1984, except 1987. Both Sloughs were sampled for pesticides and PCBs in 1988. The Harkins Slough-Watsonville Slough area, like the lower Salinas Valley, has a history of high pesticide levels in fish. In the past, chlordane, DDT, dieldrin, endosulfan, and toxaphene levels were found above the NAS guideline in both Sloughs. Levels detected in whole stickleback from Harkins Slough in 1988 are typical for the area. The 620 ppb dieldrin found at Harkins Slough is the highest concentration of this pesticide detected in 1988-89. DDT, dieldrin, endosulfan, toxaphene levels at Harkins Slough in 1988 are similar to levels found in stickleback from Watsonville Slough in past years. Sacramento blackfish from Watsonville Slough contained lower pesticide levels with only endosulfan exceeding the NAS guideline. Sacramento blackfish collected in 1985 from Harkins Slough also had low levels of pesticides. The reason for the lower levels is probably due more to the differences between stickleback and blackfish than anything else. Blackfish are primarily filter feeders feeding predominately on planktonic algae (Moyle 1976). Stickleback typically feed on bottom organisms or organisms living on plants, such as midge larvae and ostracods (Moyle 1976). In general, pesticides accumulate to higher levels in predator species than they do in herbivorous species. Determining trends for the area is difficult because of the mixture of species collected over the years. However, results from 1988 indicate that levels remain high. Watsonville Slough is listed in the 1990 WQA as having impaired water quality (SWRCB 1990a). Based on fish bioaccumulation results, Harkins Slough should also be considered for classification as an impaired water body.

The San Lorenzo area was previously sampled at seven stations (four water bodies) from 1978 to 1982. Two sites, Graham Hill Road station on Bean Creek and the Big Trees station on the San Lorenzo River, were again sampled in 1989. Both stations were sampled for metals and organic chemicals. In the past, only the Big Trees station in the San Lorenzo area had been analyzed for organic chemicals. Results from 1978, 1979, and 1981 from Big Trees showed only small amounts of DDT in fish. Fish collected in 1989 from both Bean Creek and the San Lorenzo River again show very small amounts of DDT. Historically, metal levels in fish from the San Lorenzo area exceeded criteria at most stations including the two sampled in 1989. Cadmium continues to exceed criteria at Bean Creek. Nickel, which exceeded the EDL 85 at Bean Creek, had not been detected above criteria in previous samples from this water body. Suckers were the only fish available from the San Lorenzo River in 1989. Since suckers do not have a viable liver for metal analyses, only mercury and selenium were analyzed in a filet sample. Neither trace element were found in high concentrations. A 25 mile section of the San Lorenzo River, which includes the Big Trees Station, is listed in the 1990 WQA as having intermediate or impaired water quality (SWRCB 1990a).

The south coast area of Region 3 was sampled at four stations in 1988-89: Carpinteria Marsh, Goleta Slough West, Goleta Slough East, and Mission Creek. All except Carpinteria Marsh were sampled for metals. Carpinteria Marsh was sampled for organic chemicals and was previously sampled in 1983 and 1984. A whole sample of longjaw mudsucker collected in 1983 from Carpinteria Marsh exceeded the NAS guideline for toxaphene. However, a filet sample of the same species in 1983 did not exceed the guideline. Filet samples of Pacific staghorn sculpin collected in 1984 and 1988 did not contain detectable levels of toxaphene. Besides toxaphene, only small amounts of chlordane, DDT, diazinon, and HCB have been found at Carpinteria Marsh, mostly in the 1983 whole sample. Sculpin from Goleta Slough West, sampled in both 1988 and 1989, exceeded a number of metal criteria. Arsenic was the only metal that exceeded criteria each year. Mission Creek, sampled for the first time in 1988, also exceeded the EDL 85 for arsenic in topsmelt, a primarily salt water silverside. Carpinteria Marsh, Goleta Slough, and Mission Creek are listed in the 1990 WQA as having impaired water quality (SWRCB 1990a).

Jameson Lake was sampled for metals in 1982 and for both metals and organic chemicals in 1989. Rainbow trout were collected both years. In 1982, trout exceeded the EDL 95 for zinc and the EDL 85 for silver. In 1989, no metal or organic chemical criteria were exceeded. The zinc level in 1989 was less than half the 56 ppm found in 1982. The silver concentration in 1989 was also much lower than 1982. Except for a small amount of DDT, pesticides and PCBs were not detected in the most recent sample.

Lake San Antonio, also known as San Antonio Reservoir, was regularly sampled for metals from 1982 to 1985, primarily at the Harris Creek station. Sampling was resumed in 1988 and 1989 at the San Antonio River station. Fish from this station were analyzed for metals as was previously done in 1984. High cadmium levels in fish and clams from Lake San Antonio have been documented by both the TSMP and the State Mussel Watch Program (SMWP). The highest cadmium levels in fish, all exceeding the EDL 95, were found at the Harris Creek station. Cadmium levels at the San Antonio River station were above the EDL 85 in 1984 and also in 1988 and 1989. The levels in the 1988 and 1989 white catfish samples were less than half the levels found in two 1984 brown bullhead samples from the San Antonio River station. The only other criteria exceeded at the San Antonio River station was the EDL 85 for copper in one of the 1984 samples. Other metals occasionally exceeded criteria at the Harris Creek station.

Monterey and Moss Landing Harbors have been sampled every year since 1987. All samples from Monterey Harbor were analyzed for metals. Samples from Moss Landing Harbor were analyzed for organic chemicals all three years and metals in 1988 and 1989. Kelp rockfish collected from Monterey Harbor in 1988 and 1989 consistently contained elevated levels of arsenic, cadmium, and zinc. Elevated levels of arsenic and cadmium were also found in a 1989 blue rockfish sample from Monterey Harbor. In 1987, kelp rockfish from Monterey Harbor only exceeded the EDL 85 for cadmium.

The 1.5 ppm arsenic in the 1989 blue rockfish sample is the highest concentration of this element found to date in Region 3. The previous high arsenic concentration in the Region was 1.4 ppm in white bass from Lake Nacimiento in 1981. Samples from Moss Landing Harbor, like Monterey Harbor, had elevated levels of arsenic and zinc in Pacific staghorn sculpin. Both Harbors are affected by agricultural drainage and urban pollution (i.e. industrial discharge and municipal effluent). Elevated arsenic levels may be associated with the use of arsenical pesticides or may be from a natural source. Both cadmium and zinc commonly occur in industrial and municipal discharges. Except for small amounts of DDT, pesticides and PCBs were not detected in any of the samples from Moss Landing Harbor. Both Harbors are listed in the 1990 WQA as having impaired water quality (SWRCB 1990a).

Region 4

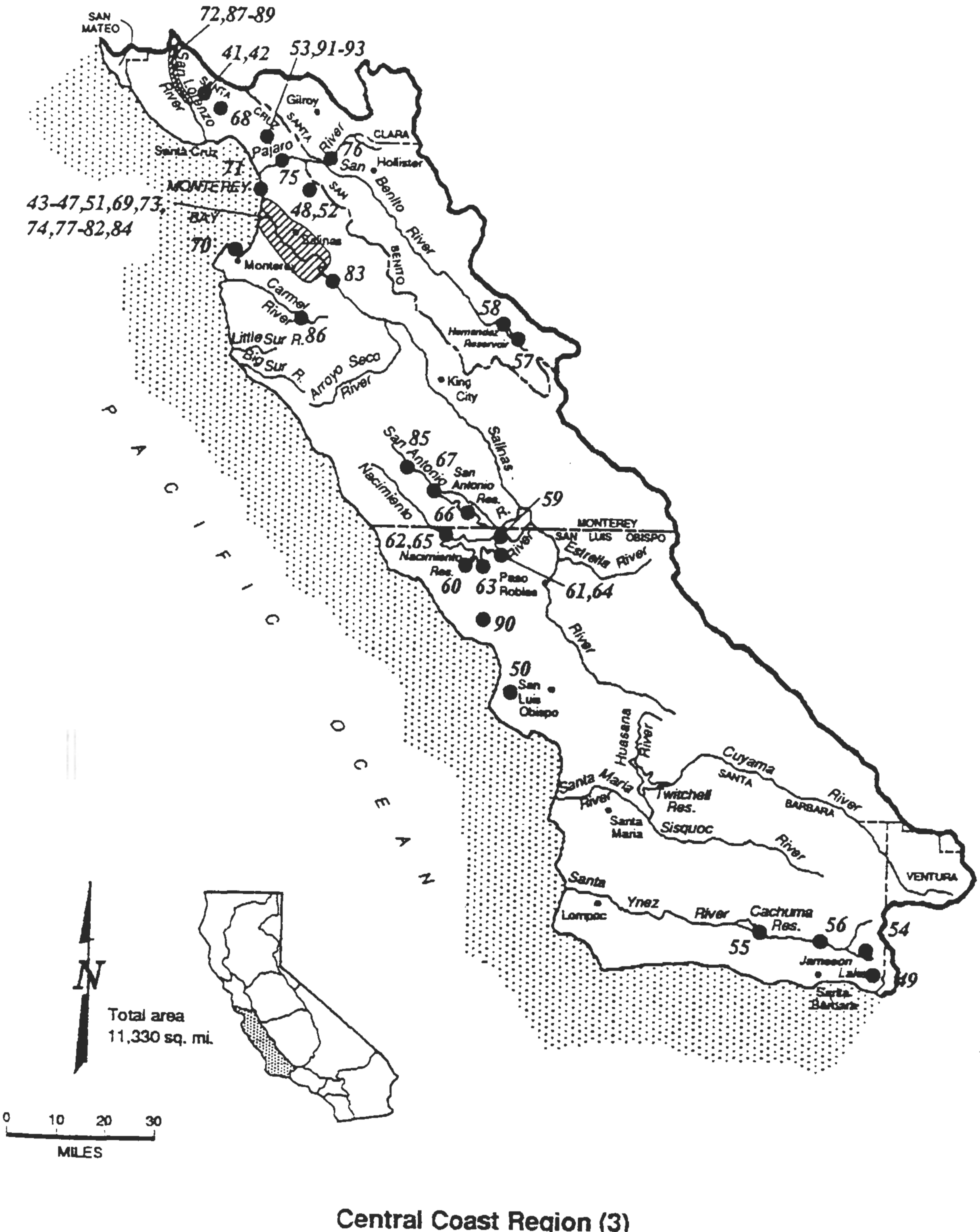
Region 4 was sampled at eight stations in 1988 and seven stations in 1989 (Figure 4). Four stations were sampled both years: Calleguas Creek, Harbor Park Lake, Mugu Lagoon, and the San Gabriel River. Casitas Lake and Rio de Santa Clara were sampled for the first time in 1988 and 1989, respectively. No special surveys were conducted in the Region. Nine fish species were collected, with goldfish dominating with six of the 17 samples. Grey smoothhound shark and shiner surf perch from Mugu Lagoon were collected for the first time in the Program. Seven of the 11 stations sampled in 1988-89 exceeded metal or organic chemicals (Table 16). DDT and methoxychlor were detected at the highest levels found to date in the Program at the Rio de Santa Clara station. Arsenic and silver were also detected at the highest concentrations yet found statewide. Cadmium, chlordane, HCB, and toxaphene were all detected at the highest concentrations found to date in the Region. Goldfish from Rio de Santa Clara contained the highest 1988-89 statewide concentrations of chlordane and toxaphene.

Calleguas Creek, Revolon Slough, and Rio de Santa Clara are adjacent water bodies which all drain into Mugu Lagoon. All three water bodies are affected by agricultural runoff. Both Calleguas Creek and Revolon Slough have been sampled regularly since 1985. Revolon Slough was not sampled in 1988 because of the lack of an adequate sample. Dacthal, DDT, and toxaphene regularly exceeded criteria at Calleguas Creek and Revolon Slough from 1985 to 1989. In 1988-89, goldfish from Calleguas Creek continued to exceed criteria for pesticides, but on a less frequent basis. Dacthal, which did not exceed criteria in 1988, was found at the highest level yet detected (110 ppb) at Calleguas Creek in 1989. The 244 ppb endosulfan detected in 1988 at the Creek is the first time this pesticide was found above criteria at this station. Previously, endosulfan levels were found, like 1989, at or near the detection limit. Toxaphene, usually found in Calleguas Creek, was not detected in 1988 for only the second time. In 1986, toxaphene was also not detected. Goldfish from the Creek continue to exceed criteria for dacthal, DDT, and toxaphene. However, levels for all three pesticides in 1989 are much lower than levels detected in past years. Chlordane and endosulfan also frequently exceed criteria at Revolon Slough. In 1989, both substances were found at levels well below criteria. Dieldrin, HCH, HCB, and PCBs, which exceeded criteria at least once at Revolon Slough, were not detected or, as in the case of dieldrin, found at just above the detection limit. The Rio de Santa Clara station, first sampled in 1989, has the distinction of being the only station in the TSMP to have exceeded three FDA action levels in one sample. The 19,270 ppb DDT in a 1989 goldfish sample from this station is the highest concentration of DDT found to date statewide. A 1985 sample of Sacramento squawfish from Blanco Drain in Region 3

Figure 5 Station Identification List

41. Bean Creek/Conference Drive
42. Bean Creek/Graham Hill Road
43. Blanco Drain/Hitchcock Road
44. Blanco Drain/Salinas River
45. Blanco East/Pump Station
46. Blanco Road Tributary/Armstrong Road
47. Blanco West/Pump Station
48. Calcagno No. 4
49. Carpinteria Marsh
50. Chorro Creek
51. Espinosa Slough
52. F Dolan No. 4
53. Harkins Slough/U/S Watsonville Slough
54. Jameson Lake
55. Lake Cachuma
56. Lake Gibralter
57. Lake Hernandez/D/S Dam
58. Lake Hernandez/San Benito River
59. Lake Nacimiento/Bee Rock Cove
60. Lake Nacimiento/Cantinas Creek
61. Lake Nacimiento/Dip Creek
62. Lake Nacimiento/Inlet
63. Lake Nacimiento/Las Tablas
64. Lake Nacimiento/Snake Creek
65. Lake Nacimiento/Tobacco Creek
66. Lake San Antonio/Harris Creek
67. Lake San Antonio/San Antonio River
68. Loch Lomond
69. Lower Tembladero Slough
70. Monterey Harbor
71. Moss Landing Harbor
72. Newell Creek
73. Old Salinas River/Molera Road
74. Old Salinas River/Monterey Dunes Way Brg
75. Pajaro River/D/S Highway 1 Bridge
76. Pajaro River/Highway 129 Bridge
77. Salinas Reclamation Canal/Airport Road
78. Salinas Reclamation Canal/Davis Road
79. Salinas River No. 2
80. Salinas River Lagoon
81. Salinas River/Blanco Drain
82. Salinas River/Blanco Road
83. Salinas River/Gonzales
84. Salinas River/Mouth
85. San Antonio River/Highway G19
86. San Clemente Reservoir
87. San Lorenzo River/Big Trees
88. San Lorenzo River/Graham Hill Road
89. San Lorenzo River/Zayante Creek
90. Santa Rosa Creek
91. Watsonville Slough/Harkins Slough Road
92. Watsonville Slough/San Andreas Road
93. Watsonville Slough/U/S Harkins Slough

FIGURE 5. TSMP Monitoring Stations 1978 - 87 (Region 3)



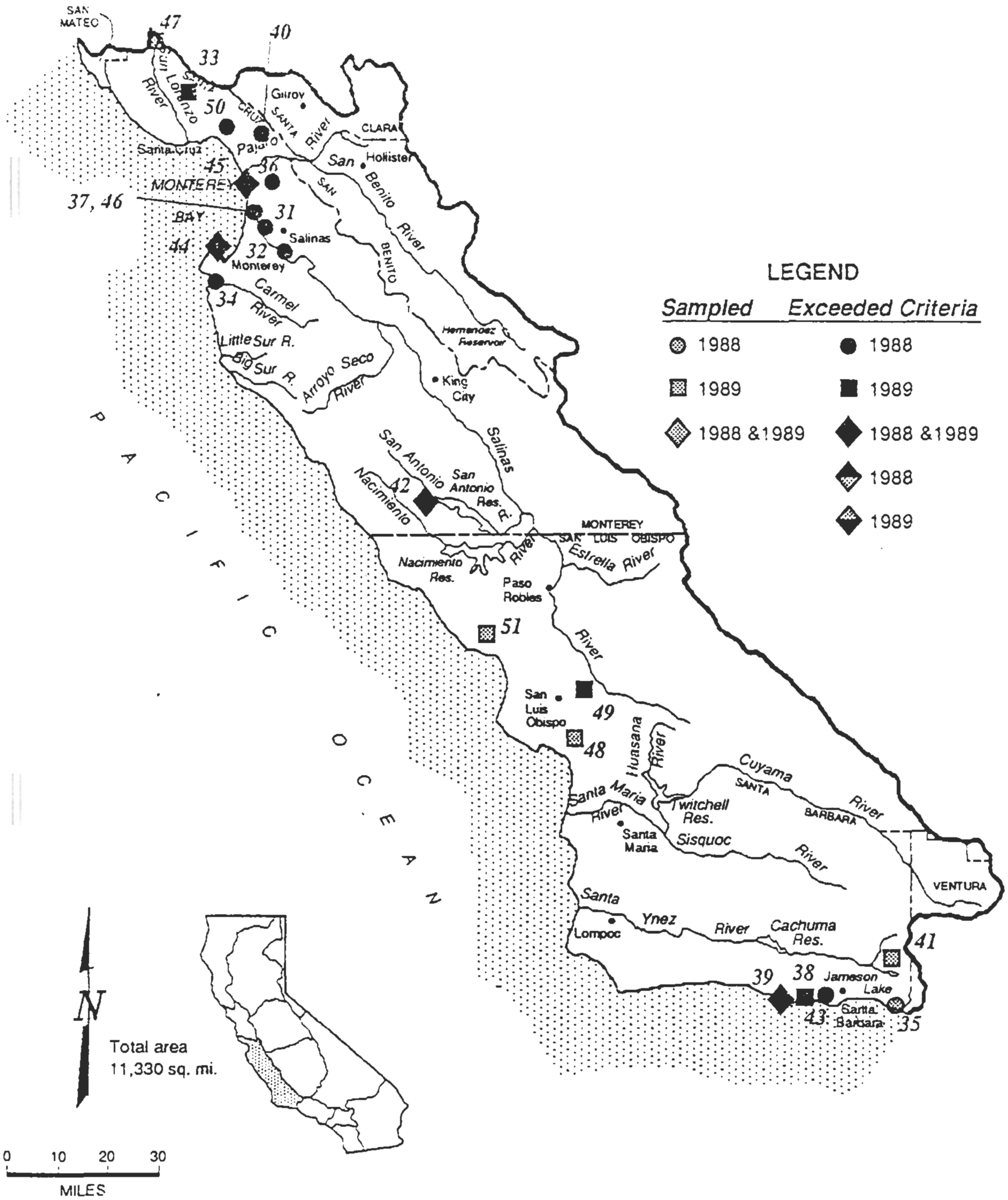
Central Coast Region (3)

CENTRAL COAST HYDROLOGIC BASIN PLANNING AREA (CC)

Figure 3 Station Identification List.

31. Alisal Slough/u/s Tembladero Slough
32. Alisal Slough/West Salinas
33. Bean Creek/Graham Hill Road
34. Carmel Lagoon
35. Carpinteria Marsh
36. Elkhorn Slough
37. Espinosa Slough
38. Goleta Slough West/Tecolotico Creek
39. Goleta Slough East/Atascadero Creek
40. Harkins Sough/u/s Watsonville Slough
41. Jameson Lake
42. Lake San Antonio/San Antonio River
43. Mission Creek/Highway 101
44. Monterey Harbor
45. Moss Landing Harbor
46. Salinas Reclamation Canal/u/s Tembladero Slough
47. San Lorenzo River/Big Trees
48. San Luis Obispo Creek/d/s San Luis Obispo
49. San Luis Obispo Creek /u/s San Luis Obispo
50. Watsonville Slough/Lee Road
51. Whale Rock Reservoir

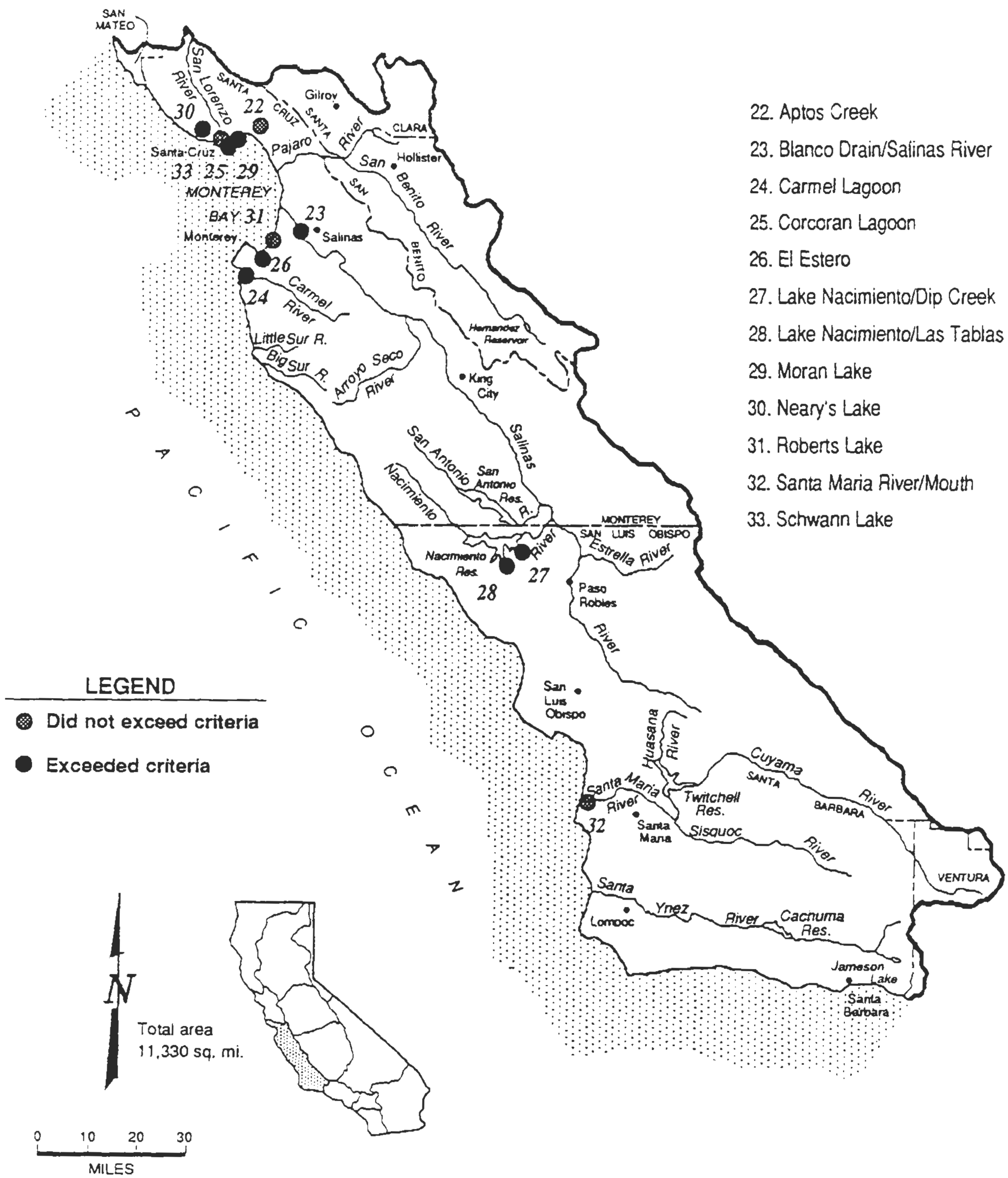
FIGURE 3. TSMP Monitoring Stations 1988 - 89 (Region 3)



Central Coast Region (3)

CENTRAL COAST HYDROLOGIC BASIN PLANNING AREA (CC)

FIGURE 3. TSMP Monitoring Stations 1991 (Region 3)

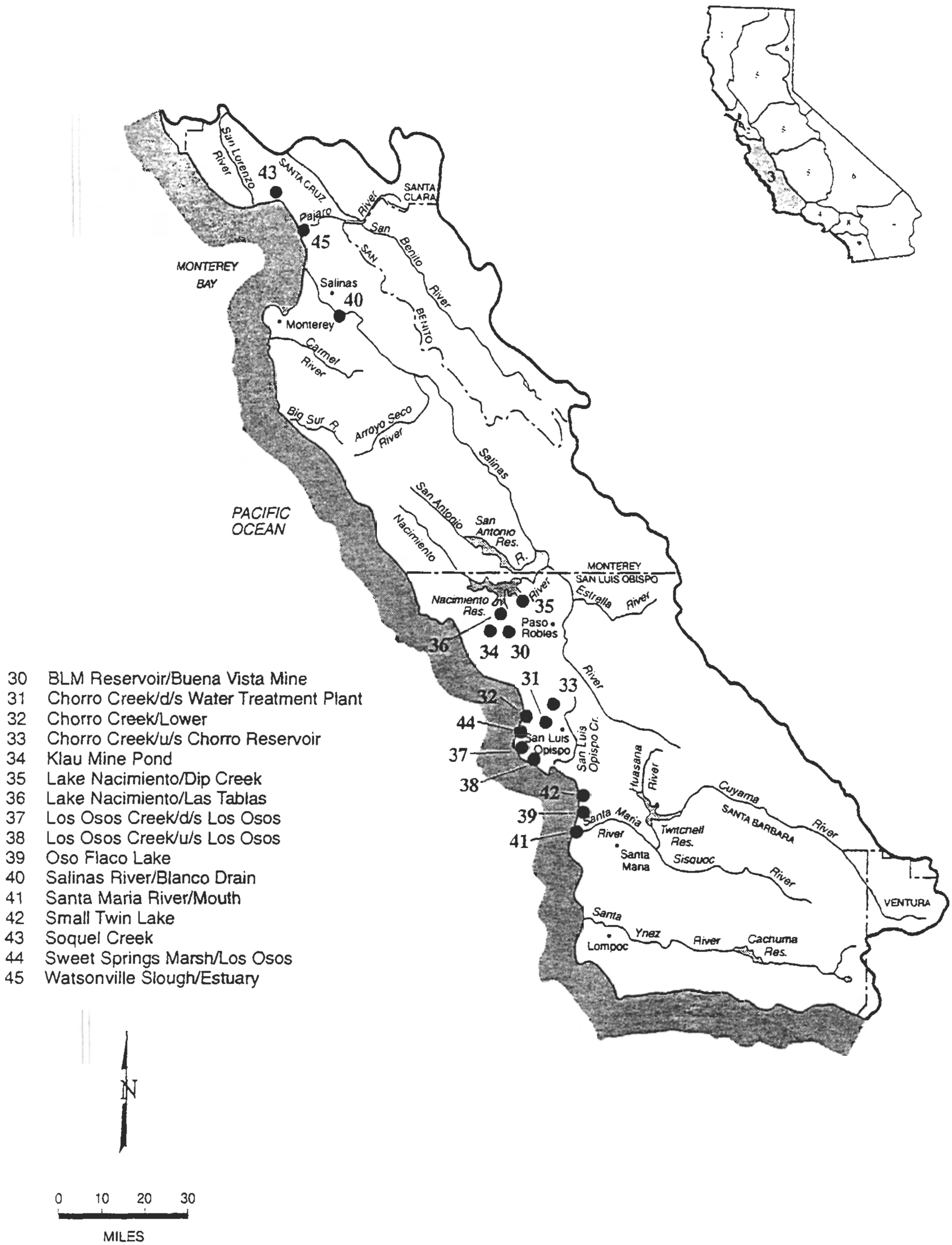


Central Coast Region (3)

CENTRAL COAST HYDROLOGIC BASIN PLANNING AREA (CC)

Figure 3. TSMP Monitoring Stations 1992-93 - Central Coast Region (3)

CENTRAL COAST HYDROLOGIC BASIN PLANNING AREA (CC)



Appendix 5

QA/QC Plan for Water Quality Monitoring

Watershed Institute

&

Moss Landing

Marine Laboratories

<u>Comprehensive Watershed Management</u>

Quality Assurance
Project Plan

July 1996

Preface

This Comprehensive Watershed Management Program was developed to assimilate the efforts of many local, state and federal agencies to effectively restore and monitor local wetland areas. Such "coordination of multiple agencies and private interests" has been identified as essential to watershed management by the State Water Resources Control Board and the EPA 319 and 205j funding programs. Multiple agencies will play essential roles in defining the direction of restoration actions through a technical advisory committee (TAC) and assisting in water quality monitoring procedures and analysis.

This QAPP is meant to be a compliment and addition to the individual QAPP reports created by California Department of Fish and Game, Bay Protection and Toxic Cleanup Program, Long Marine Lab, and Moss Landing Marine Labs previously accepted by the State Water Resources Control Board as fulfilling EPA quality assurance procedures (Stanley and Verner 1983). These QAPP's are cited where appropriate.

Table of Contents

1.0 Introduction

Movement of water from the land to the sea is radically modified in the Salinas Valley, the primary watershed of the Monterey Bay. Water is drained into ditches adjoining agricultural fields, into central collecting ditches that were once magnificent creeks, into the Salinas River which is now a flood control channel, and finally into Monterey Bay. Dozens of creeks were long ago converted to devegetated ditches. Thousands of acres of wetlands are ditched and dried, reducing flood and natural water quality control and the ground water recharge necessary to forestall saltwater intrusion. Most of the wetland landscape is now gone (Gordon 1977).

The second most important environmental problem in Monterey Bay and throughout much of the state, is nonpoint source pollution. Year after year, farm chemicals drain into a ditch system which empties directly into the Monterey Bay Marine Sanctuary. The wetland complex is an extensive biological filter. It dilutes, filters, retains, and biologically degrades toxic chemical. Farm runoff is physically filtered by the wetland, reducing downstream toxicity (Gearhart 1992, Puckett 1993). The overall effect of the wetland filter is a dramatic reduction in chemical concentrations and potential toxicity to wildlife.

The goals of this watershed monitoring program are to identify and monitor sites with high levels of nonpoint source pollution and monitor cleaner areas for possible temporal differences in water quality. This program will also determine the effectiveness of restored wetlands as a biological filter for nonpoint source pollution by creating a water quality database for those areas before (or during) and after restoration.

1.1 Quality Assurance Program for MLML Comprehensive Watershed Management Plan.

The Moss Landing Marine Labs Watershed Comprehensive Watershed Management Plan funded by the State Water Resources Control Board 319 & 205j programs must conform with all requirements specified in the EPA mandatory QA guidelines (Stanley and Verner 1983). As part of this program, every environmental monitoring and measurement project is required to have a written and approved Quality Assurance Project Plan (QAPP).

The QAPP for the Comprehensive Watershed Management Plan (this document) describes the quality assurance and quality control activities and measures that will be implemented to ensure that the data will meet all quality criteria established for the project. All project personnel must be familiar with the policies, procedures, and objectives outlined the this quality assurance plan to assure proper interactions among the various data acquisition and management components of the project. This document will be revised as appropriate, as changes are made to the existing QA program and as additional data acquisition activities are implemented. The EPA guidance (Stanley and Verner, 1983) states that the 15 items shown in Table 1 should be addressed in the QAPP.

Table 1. Sections in this report that address the 15 subjects required in a Quality Assurance Project Plan.

Quality Assurance Subject	MLML QAPP
Title page	Title page
Table of Contents	Table of Contents
Project description	Section 1
Project organization and responsibilities	Section 1.2
QA objectives	Section 1
Sampling procedures	Section 2, 5.1-4
Sample custody	Section 5.0
Calibration procedures	Section 5.5
Analytical procedures	Section 5.5
Data reporting	Section 6
Internal QC checks	Section 5.5
Performance and system audits	Section 5.5
Preventive maintenance	Section 5.5
Corrective action	Section 5.5
QA reports to management	Section 6

1.2 Project Organization and Responsibilities

Contract Managers

Frank Barron	Association of Bay Area Governments
Howard Kolb	Water Quality Control Board, Region 3

MLML Staff

John Oliver	Project Director
Ross Clark	Assistant Project Manager/Water Quality
Jo Guerrero	Assistant Project Manager/Regional Planning
Peter Slatery	Scientist
Sue Shaw	Restoration Coordinator

Affiliate Agencies and Laboratories

Mark Stephenson	California Department of Fish and Game-Mussel Watch/BPTC
John Newman	Long Marine Laboratories Synthetic Organic Lab.

2. Sample Design

Nonpoint source pollution (NPSP) can be monitored in the watershed management areas or wetlands in a highly effective surveillance and source control program. Water quality can be measured coming into and going out of the wetland, and in both sediment and biological tissues. Pesticide levels can be measured in water during periods of peak input to the watershed as well as bivalve tissue in a California Department of Fish and Game Mussel Watch protocol (Stephenson et. al 1979,1980). Bivalves accumulate chemicals over a longer period of time as an indicator of problem watershed sites, chemicals, and activities. The monitoring will indicate clean water or the presence of problems that can be investigated in a research project and/or controlled by cooperative and well directed actions. The monitoring program can be scientifically rigorous, inexpensive, and begin a thorough water quality data base. Monitoring information will be useful in land use planning and practices through direct and indirect links with government agencies and community organizations.

Selection of sample locations will be based around restoration areas, flow from highly impacted areas, historical data (Mussel Watch), and intermittent sampling of less impacted areas. Nitrates will be used as an inexpensive sampling indicator of agricultural runoff, suggesting correlative levels of pesticides. Nitrates will be sampled monthly or during significant rain events to estimate runoff and potential pollution load within many of the local waterways. Bivalves (*Corbicula fluminea*) will be used to accumulate pollutants over a longer period (1-2 months) and will be analyzed for pesticide concentrations.

The goals of this watershed monitoring program are to identify and monitor sites with high levels of NPSP and monitor cleaner areas for possible temporal differences in water quality. This program will also determine the effectiveness of restored wetlands as a biological filter for NPSP by creating a water quality database for those areas before and after restoration is begun. Water quality will be assessed using direct water sampling, pollution bioaccumulation within outplanted filter feeders, and sediment sample concentrations. Specific NPSP monitoring activities will include:

a: For frequent monitoring of wetlands water during rainy season (Dec-Mar), nitrate concentrations are used as an indicator of NPSP because of the simple/cheap methods of sampling and analysis, and it is common in run-off from agriculture and grazing land, two primary land uses within this watershed. Two water samples will be taken at least once monthly during the four month rainy season.

b: More extensive analysis of water contaminants will be done using *Corbicula fluminea* as a bioaccumulator on several waterways of interest. These samples will be analyzed for synthetic organic contaminants of concern. A one month bioaccumulation of 1 *Corbicula* sample will be taken per area of interest. These samples will give further information on seasonal pollution levels and suggest areas for future more statistically robust sampling implementation.

c: Sediment samples will be taken from depositional areas within wetland/stream areas of concern and analyzed for synthetic organic pollutants of concern.

d: Turbidity testing of waterways, identifying sediment load above and below wetlands, will be conducted to study filtering of sediment by wetland systems.

A full list of sample comparisons to be used for determining water quality and restoration impact is listed in appendix A.

3. Record Keeping and Field Measurement

Information associated with each sample will be noted on field data sheets and later entered into the database. Information will include station name, site location, GPS coordinates, date, time, and field observations. Field measurement may include temperature, dissolved oxygen, salinity, turbidity, and flow rate.

4. Cleaning Procedures

All containers used for water sampling will be soaked in a Micro (brand) detergent, tap water rinse, DI water rinse, 10% HCl rinse, DI rinse and air dry.

All containers used for sediment collection will be trace metal and synthetic organic clean and stated in BPTC QAPP, 3.6.2 (1994) (see appendix B).

Bivalve samples will be wrapped in synthetic organic clean foil and double zip-lock bagged as stated in Department of Fish and Game QAPP, Method# Samp-Mus 6.1 (1992) (see appendix C).

5. Field and Laboratory Operations.

All sample exchanges between laboratories will be documented using chain-of-custody forms and held under proper conditions until the time of analysis.

5.1 Water Samples

Water samples will be taken with a one liter high density polyethylene bottle attached to an extension pole, dipped into the water source till full. All field measurements will be taken from water decanted from this sample. The remainder will be sealed and stored in an ice chest with ice and returned to the laboratory. Samples will be measured or properly processed within 24 hours from the time taken to minimize deterioration of samples.

5.1.1 In-Field Water Quality Measurements

All samples will be analyzed in the field for multiple water quality parameters including Temperature (°C), pH, Conductivity/Salinity (μS), O2 Concentration(ppm), and Turbidity (NTU). All measurments will be taken with the use of a Solomat, Multiparameter Water Quality Probe field meter (Neotronics). Daily calibration and replicate measurements will ensure that accuracy and presision of all measurements will be within the parameters specified by the manufacturer (appendix E).

5.1.2 Water filtering and Storage

Particulate matter will be remove from samples prior to freezing to decrease confounding interactions with laboratory procedure. Particulates will be remove either with multiple filters with minimum size of 0.45microns or spun within a temperature compensated centrifuge, decanted and filtered with a single 0.45micron filter. Samples will then be frozen in properly cleaned and labeled high density polyethylene jars and stored until the time of analysis.

5.1.3 Nitrate/Nitrite Analysis

Nitrates/nitrites will be measured using a cadmium reduction colormetric method (Standard Methods 1992). Samples will be thawed but not warmed, mixed and sampled using a flow-through nutrient autoanalyzer. Reagents will be made daily and standard curves will be maintained. Dilutions of samples will be made using deionized water for samples exceeding the range of detection/standards. Nitrate/nitrites will be measured as ppm NO_3.

5.1.4 Sample Holding & Method Comparison

Water samples will be frozen for a maximum of 2 months till laboratory analysis of nitrate/nitrite can be preformed. This holding procedure has been found to limit nitrate degradation for up to three months after collection and has been used exclusively by Moss Landing Marine Labs when immediate analysis is impossible. To further confirm the absence of nitrate degradation using this sample holding procedure, samples of various nitrate concentrations will be analyzed immediately after collection and compared to replicate samples frozen for two months. EPA storage criteria including acidification of sample to pH<2 will not be used because of interference with the cadmium column reaction procedure.

5.2 Sediment Collection

Sediment samples will be taken from areas suggested to be high in agricultural runoff from nitrate levels in water samples. Sediment will be collected below the waterline using diver core techniques in accordance with the California Bay Protection and Toxic Cleanup QAPP (1994, see summary in appendix B). Sediment samples will be placed in properly cleaned containers, properly marked and frozen until the time of analysis at the Long Marine Laboratory (see appendix B for holding times). Samples will be analyzed for appropriate synthetic organic compounds as suggested by the Department of Fish and Game and Bay Protection and Toxic Cleanup program scientists. Laboratory procedures for synthetic organic chemical extraction and analysis within sediments is outlined in the Long Marine Lab/ Bay Protection and Toxic Cleanup QAPP (1994). Chemical concentrations within samples will be measured as ppm or ppb dry weight.

5.3 Bivalve Bioaccumulation

The Freshwater Clam (*Corbicula fluminea*) will be placed within waterways of concern determined from nitrate levels in water samples or historic bioaccumulation data. *Corbicula* deployment bags will be placed within the waterways for approximately 4-6 weeks during the rainy/high flow season. Samples will be collected after the appropriate period and wrapped in cleaned foil and double zip-lock bagged as stated in the Mussel Watch protocol (Department of Fish and Game QAPP 1992). Samples will be frozen at -20 Fahrenheit until analyzed for synthetic organic concentrations. Clams will be dissected and homogenized in accordance with Department of Fish and Game QAPP (1992, see summary in appendix C). Samples will be analyzed for appropriate synthetic organic compounds as suggested by the Department of Fish and Game and the Bay Protection and Toxic Cleanup program scientists. Laboratory procedures for synthetic organic chemical extraction and analysis within tissues is outlined in the Department of Fish and Game QAPP 1992 (MacLeod et. al 1993) . Chemical concentrations within samples will be measured as ppm or ppb dry weight.

5.4 Intralaboratory QA

Each Laboratory QAPP has been reviewed and determine to fulfill the needs of the monitoring program, and therefore, each analytical laboratory will be responsible for quality assurance program procedures specific to its individual protocol. All calibration and analytical procedures, internal QC checks, corrective actions, preventative maintenance, and performance and system audits will be in accordance with these QAPP standards (Department of Fish and Game QAPP 1992, Bay Protection and Toxic Cleanup QAPP 1994). Quality assurance reports from individual laboratories will be obtained with sample results to assure compliance with QA procedures. QA reports will be reviewed to assure compliance and fulfillment of laboratory QA procedures, and submitted with the hard copy of the final data report to the Contract Manager. A Quality Assurance Final Report will review all QA procedures and be included as supplemental database information.

6.0 Data Reporting

In addition to paper data sheets, all data collected by field crews are recorded into an IBM dBase-4 file. Data sheets and data base description are present in appendix D. Following analysis of the samples, a data report including appendix with pertinent raw data will be presented to the Contract Manager. An electronic file (IBM diskette) will also be made available. Database structure can be manipulated to assure compatibility with all requirements of individual grant programs and funding agencies within the confines of the MLML/Watershed Institute computer software abilities. Additional modifications may require assistance from specific agencies of concern.

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Appendix A

Sampling Design for Addressing NPSP Questions

Questions:

A. Levels of NPSP within all watershed project areas

A: Nitrate Monitoring at 1 or more stations within each project every month or every substantial rain event.

B: Coliform samples will not be taken, but recent information will be included.

C: Suspended material analysis at all sites for sediment load.

D: *Corbicula* will be placed in areas of interest to bioaccumulate other contaminants.

Analysis: **A,B,C,** Comparison between project sites for each of these indicators will give evidence of possible areas of high pollution and distinguish between pollution types-

High Coliform=farm animals
High Nitrate = agriculture input/farm animals
High Suspended Materials = erosion of either but probably visible.
Site X Indicator

D *Corbicula* will give evidence for other organic and metal pollutants beside indicators. Comparison between other indicators and organic data will give understanding of relationship between simple and more intense sampling tech.

Site X Accumulated Chem.
Accum Chem. X Indicators

B. Determine effectiveness of wetlands as a biological filter.

A: Multiple inflow and outflow samples of all appropriate sites for nitrates/sediment/Coliform.

B: Inflow/outflow *Corbicula* samples at certain sites for more intensive study of NPSP filtering.

Analysis: Comparison of inflow and outflow samples within a single water system for above indicators
Comparison of *Corbicula* analysis within a water system for indication of filtration of organics and metals.
Comparison between *Corbicula* and indicators to test filtration capabilities between chemicals.

Inflow/Outflow X Indicator
Inflow/Outflow X Accum. Chem.

WEOP Restoration Monitoring Outline

Systems of Interest	Inflow	Outflow	*Corbicula*
Hansen's Slough	yes	yes	yes
Natividad	yes	yes	yes
Castroville Slough	yes	=Tottino	no
Tempbadero Slough	yes	yes	possible
Moro Cojo Slough	yes	?	no
Porter Ranch	no	yes	no
Walker Valley	yes	yes	no
Dairy	several	yes	no
Fort Ord	yes	yes	no
Tottino marsh	=Castroville	yes	no

APPENDIX B

This Appendix is an excerpt of the Bay Protection and Toxic Cleanup Program QAPP. Sections are labeled by corresponding section numbers and omissions are of information not associated with this project.

3.5 SAMPLE ACCEPTABILITY CRITERIA

After the filled sampler was secured on the transom, or gunnel, or deck, or gained by diver core, the sediment sample will be carefully inspected. The following acceptability criteria were met:

- o Sampler was not over-filled (i.e., the sediment surface is not pressed against the top of the sampler).
- o Overlying water was present, indicating minimal leakage.
- o Overlying water was not excessively turbid, indicating minimal sample disturbance.
- o Sediment surface was relatively flat, indicating minimal sample disturbance.
- o Desired penetration depth was achieved (i.e., 20 cm).
- o Sample was muddy (>30% fines), not sandy or gravelly.
- o Sample did not include excessive shell and organic debris.

If a sample did not meet all the above criteria, it was rejected.

3.6 CLEANING PROCEDURES

This section describes cleaning of sediment sampling equipment, sediment storage containers, and sediment sampler.

3.6.1 Field equipment

All sampling equipment (i.e., containers, container liners, scoops, water collection bottles) was be made of non-contaminating materials and will be pre-cleaned and protectively packaged prior to entering the field. Sample collection gear and samples were only handled by personnel wearing non-contaminating polyethylene gloves. All sample collection equipment (excluding the sediment sampler) were cleaned by using the following sequential process:

Two-day soak and wash in Micro (brand) detergent, three tap-water rinses, three deionized water rinses, a three-day soak in 10% HCl or HNO_3, three Type II Milli-Q (brand) water rinses, air dry, three petroleum ether (PE) rinses, and air dry.

All cleaning after the Micro (brand) detergent step was performed in a positive pressure "clean" room to prevent airborne contaminants from contacting sample collection equipment. Air supplied to the clean room was filtered.

The sediment sampler was cleaned prior to entering the field by utilizing the following sequential steps: a vigorous Micro (brand) detergent wash and scrub, a tap-water rinse, air dry, a 10% HCl or HNO_3 rinse, and a methanol rinse.

3.6.2 Sample storage containers

Sample storage containers were cleaned in accordance with the type of analysis to be performed upon its contents. All containers were cleaned in a positive pressure "clean" room with filtered air to prevent airborne contaminants from contacting sample storage containers.

Containers for trace metal analysis media (sediment, archive sediment, pore water, and subsurface water) were cleaned by: a two-day Micro (brand) detergent soak, three tap-water rinses, three deionized water rinses, a three-day soak in 10% HCl or HNO_3, three Type II--Milli-Q (brand)-- water rinses, and air dry.

New containers for synthetic organic analysis media (sediment, archive sediment, pore water, and subsurface water) and additional teflon sheeting cap-liners are cleaned by: a two-day Micro (brand) detergent soak, three tap-water rinses, three deionized water rinses, a three-day soak in 10% HCl or HNO_3, three Type II Milli-Q (brand) water rinses, air dry, three petroleum ether (PE) rinses, and air dry.

3.6.3 In-field cleaning

To avoid cross-contamination, all equipment used in sample handling was thoroughly cleaned before processing any sample or portion thereof. The sediment sampler was cleaned prior to sampling a site by: rinsing all surfaces with seawater, scrubbing all sediment sample contact surfaces with Micro (brand) detergent, rinsing all surfaces with seawater, rinsing sediment sample contact surfaces with 10% HCl or HNO_3, and rinsing all sediment sample contact surfaces with methanol. If sites had multiple stations, the sediment sampler was scrubbed and cleaned between stations in the same manner as it was between sites.

Trace metal-free and synthetic organic-free polystyrene scoops were used to transfer sample mud from the grab to the sample holding container. The sample holding container was composed of noncontaminating polyethylene or polycarbonate.

3.7 SEDIMENT SAMPLE COLLECTION

3.7.2 Sediment sample collection utilizing diver cores

If water depth did not permit boat entrance to a site (e.g.. <8ft.), divers sampled that site using sediment cores (diver cores). Cores consist of a four-inch diameter polycarbonate tube, one-foot in length, including plastic end caps to aid in transport. A plunger or the divers gloved hand was covered with a plastic laboratory glove and used to extrude the mud for collection. All sample acceptability criteria were met.

Divers entered a study site from one end and sampled in one direction so as to not disturb the sediment with feet or fins. Cores were taken to a depth of at least six inches. Cores were removed and a plunger or glove was placed on the bottom of the core. The sample was be extruded through the top of the core, allowing surface water to run off slowly, as stated for the grab sample procedure. The mud was pressed out of the top end of the core to the prescribed depth of 2-cm and cut with a polycarbonate spatula, and will be deposited into the cleaned polyethylene tub. Additional samples were taken with the same core tube until the required volume was attained. Diver core samples were treated similar to grab samples, with teflon sheets covering the sample and nitrogen vented.

Data sheets were completed including latitude and longitude, salinity, temperature, etc., as outlined in Section *3.3.1*. If sub-surface water samples were requested, they were taken in an area of the site not yet disturbed by samplers. If replicate samples were required, new core tubes were used and new laboratory gloves were placed over the plunger. Sampling was conducted far enough apart to ensure no disturbance by the samplers during the previous replicate.

3.7.3 Transport of sample containers

Six-liter sample containers were packed (three to an ice chest) with enough ice to keep them cool for 48 hours. Each tub was sealed in two pre-cleaned, large plastic bags closed with a cable tie to prevent contact with other samples or ice or water. Ice chests were driven back to the lab by the sampling crew or flown by air freight within 24 hours of collection.

3.8 HOMOGENIZATION AND ALIQUOTING OF SAMPLES

3.8.1 In-field sampling

For the sediment sample, the top 2-cm was removed from the grab and placed in the 6-liter polyethylene container. Between grabs or cores, the sediment in the container was covered with a teflon sheet and the container covered with a lid and kept cool. When an adequate amount of sediment had been collected, the sample was covered with a teflon sheet assuring no air bubbles. A second, larger teflon sheet was placed over the top of the container to ensure an air tight seal, and nitrogen was vented into the container to rid it of oxygen.

3.8.2 In-laboratory homogenization and aliquoting

3.8.2.1 Homogenization

Samples remained in ice chests (on ice, in double-wrapped plastic bags) until the containers were brought back to the lab for homogenization. All sample identification information (station numbers, etc.) was recorded on COC and

COR forms prior to homogenizing and aliquoting. A single container was placed on plastic sheeting while also remaining in original

8.2.2 Aliquoting and Storage:

By using a teflon scoop, all prelabeled jars will be filled and stored in freezer/refrigerator until analysis. Samples will be placed in boxes sorted by analysis type and leg number. The first sample taken is for AVS if applicable, and then aliquoted to trace metal, organics, porewater, and bioassay containers. The sample containers for bioassays are then placed on ice or in a refrigerator (4 C). Containers for chemistry are stored in a freezer (-25 C).

8.2.3 Temperature and Holding Time

Analysis	Temperature	Storage time
Trace metals	-20 C	6 months
Synthetic organics	-20 C	6 months

APPENDIX C

This appendix is an excerpt of the California Department of Fish and Game Mussel Watch Laboratory QAPP. Sections are labeled by corresponding section numbers and omissions are of information not associated with this project.

Method # Samp-MUS

Sampling and Processing Trace Metal and Synthetic Organic Samples of Marine Mussels and Freshwater Clams.

1.0 Scope and Application

The following procedures are for sampling and processing trace metals (**TM**) and synthetic organics (**SO**) in marine mussels and freshwater clams.

2.0 Summary of Methods

2.1 Collect mussels or clams. Musssels or clams to be transplanted are placed in a polypropylene mesh bags and deployed.

2.2 Once the samples are retrieved they are transported to "clean lab" where they are cleaned, dissected, and homogenized.

3.0 Interferences

3.1 Solvents, reagents, glassware, and other samples processing hardware may yield artifacts and/or elevated baselines, causing misinterpretation of chromatograms. All materials should be demonstrated to be free from interferences under the conditions of the analysis by running method blanks initially and with each sample lot. Specific selection of reagents and purification of solvents by distillation in all-glass systems are required. High-purity, distilled-in-glass solvents are commercially available (e.g., Burdick and Jackson laboratories, Muskegon, MI.). An effective way of cleaning laboratory glassware is covering with aluminum foil, heating at 450° C for several hours, and rinsing with polar and non-polar solvents before use.

6.0 Sample Collection, Preservation, and Handling

6.1 In the field, sources of contamination include sampling gear, grease from ship winches or cables, ship engine exhaust, dust, and ice used for cooling. Efforts should be made to minimize handling and to avoid sources of contamination. This will usually require that resection (i.e., surgical removal) of tissue be performed in a controlled environment (e.g., a laboratory). The samples should be wrapped in aluminum foil and immediately frozen with dry ice in a covered ice chest. Ice should be in water tight plastic bags for transporting live shellfish.

6.2 To avoid cross-contamination, all equipment used in sample handling should be thoroughly cleaned before each sample is processed. All instruments must be of a material that can be easily cleaned (e.g., stainless steel, anodized aluminum, or borosilicate glass). Before the next sample is processed, instruments should be washed with a detergent solution, rinsed with tap water, rinsed with a high-purity acetone, and finally rinsed with Type II water.

6.3 Resection should be carried out by or under the supervision of a competent biologist. Each organism should be handled with clean stainless steel, quartz, or Teflon instruments (except for external surfaces). The SO specimens should come in contact with precleaned glass surfaces only. Polypropylene and polyethylene surfaces are a potential source of contamination for SO specimens and should not be used.

6.4 The tissue sample should be placed in a clean glass or TFE container which has been washed with detergent, rinsed twice with tap water, rinsed once with distilled water, rinsed with acetone, and finally rinsed with high-purity petroleum ether (PE).

6.5 The U.S. EPA and other federal agencies (e.g., National Bureau of Standards) have not yet provided specific guidance regarding holding times and temperatures for tissue samples to be analyzed for semi-volatile organic compounds. Until U.S. EPA develops definitive guidance, the following holding conditions should be observed. Resect tissue samples should be maintained at -20^{o} C and extracted as soon as possible, but within 10 days of sample receipt. Complete analyses should be performed within 40 days. These holding times are based on the Laboratory Program requirements for sediment.

6.6 All SO containers must be glass and be prerinsed three times with petroleum ether (PE).

6.7 All TM containers must prewashed with detergents, tap water, dionized water, acids, and Type II Milli-Q water. Plastic and glass containers are both suitable.

7.0 Procedure for Sample Preparation and Collection

7.1.3 The polypropylene mesh is cut into sections 36" long. A knot is tied in one end and a cable tie is placed on the inside of the knot strenghtening the knot.

7.2 Sample Collection

7.2.1 The transplant mussels (Mytilus californianus) are from Trinidad Head (Humboldt Bay intensive survey), Montana de Oro (Diablo Canyon intensive survey), and Bodega Head (all other statewide transplants). The freshwater clam (Corbicula fluminea) sources are Lake Isabella and the American River. The samples from the American River should be depurated for six weeks in Aptos Creek before transplanting. Analyze mussel samples for background comtaminates prior to transplanting. Mussels of 55mm to 65mm in length are recommended. Fifty mussels are collected for each TM and each SO sample. An additional 300 mussels are needed for controls. For the collection of resident sample where only one or two samples are being collected the mussels are placed directly into freezer storage bags.

7.2.4 Collecting freshwater clams.

1. Clams (Corbicula fluminea) measuring 20 to 30 mm are collected by hand in water depths less than 1 m. 100-200 clams are needed for each TM and each SO sample. Collect 300 clams for control TM and SO samples at this time. Fifty tranplant mussels are placed in each mesh bag(See section 7.1.3). Each bag represents one TM or one SO sample. A knot is tied in the open end of mesh bag and reinforced with another cable tie. Inside that cable tie place an open cable tie which will be used to connect the sample to a buoy. The mussels in the mesh bag are divided into three groups of approximately equal size and sectioned with two more cable ties.

7.3.2 Once bagged, the clams are stored in an ice chest (cooled with ice) for no more than 24 hours. The ice is placed in Ziplock bags to avoid contamination. If samples are held for longer than 24 hours they are placed in holding tanks at the Granite Canyon Lab. Control samples for both SO and TM are also removed from the tank. Clams (100-200) are placed in nylon mesh bags using identical procedures to those used with mussels (section 7.3.1).

7.3.4 Sample Deployment.

7.3.6 The mussels are attached to a shallow water transplant system that consists of a buoy system constructed with a heavy weight anchor chain(about 100lbs) or screw in earth anchor, 16mm polypropylene line, and a 30cm diameter subsurface buoy. In some cases (e.g. Cayucos transplant) the sample may be hung on polypropylene lines from a pier or other surface structure, however, creosote-coated wooden piers should be avoided because they are a potential source of contamination. In some cases the mussels are hung from a floating dock.

7.3.7 The clams are deployed by attaching the mesh bag to wooden or PVC stakes hammered into substrate. The bags containing clams are typically deployed 15 cm or more off the bottom.

7.3.8 Transplants are deployed for an interval of at least one month.

7.4.1 The transplanted or resident and control mussels and clams are analyzed for TM are placed into three ziplock polyethylene bags (4 mm thickness).

7.4.2 All mussels and clams to be analyzed for SO are placed in an aluminum foil bag. The bags are constructed of two layers of "heavy duty" aluminum foil. Prior to use these bags are cleaned by heating to 500° C or by rinsing in hexane. The sample is first wrapped in a foil bag, then placed in two polyethylene Ziplock bags. The samples should be stored at or below -20C until analyzed.

7.5 Laboratory Preparation

7.5.1 **Note:** TO MINIMIZE CONTAMINATION, ALL SAMPLES ARE PROCESSED UNDER "CLEAN ROOM" CONDITIONS. Acceptable criteria from Flegal (1982) are recommended. Shoe covers and lab coats are worn in the laboratory to minimize transport of contaminants into the laboratory. The trace metal laboratory has no metallic surfaces, with benchtops, sinks and fume hoods constructed of acid resistant plastic to avoid metal contamination. A filtered air supply (class 100) which provides a positive pressure clean air environment is an important feature for reducing contamination from particulates.

7.6 Sample Dissection for Bivalves.

7.6.1 For both TM and SO: Frozen mussels are thawed, removed from the Ziplock bags, and cleaned of epiphytic organisms and debris under running deionized water. Dissection is ideally done on thin sheets of teflon if not availabe for metals use polypropylene boards.

9.2 Sample Archive: All remaining sample homogenates and extracts are archived at -20^{o} C for future analysis. A few of the more important original mussel and clam samples are also archived for future analysis.

9.3Field Blanks: When transplanting mussels or clams a control sample travels with the samples to be transplanted and is returned to the laboratory and labled "Travel Blank".

9.4 Field Replicates: No Field replicates will be taken.

9.5 A record of sample transport, receipt and storage is maintained and available for easy reference.

9.6 All samples are prepared in a clean room to avoid airborn contamination (see section 7.5.1)

11.0 REFERENCES

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APPENDIX D

Data Base Description

Sta_num	Site identification number
Station	General area of sample
Date	Date sample taken
Ref_no	Individual sample identification number
Location	Specific site within that Station
Oxygen	Oxygen as ppm
pH	pH
Temp.	Temperature as centigrade
Conductivity	Conductivity as μS
Turbidity	Turbidity as NTU
NO3_um	Nitrates as micromoles
NO3_ppm	Nitrates as parts per million NO3

1. Forty-five mussels are dissected per sample. These are split into 3 groups of 15. Each group of 15 creates A, B, and C replicates. If there are fewer than 45 mussels divide the mussels up into three equal samples. Make sure to note total number of bodies in each jar.

2. The adductor muscles are severed with a scapel and the mussel is pried open with the plastic end of the scapel. The gonads are then removed. The first 15 gonads are placed in a preweighed container and weighed. The gonads can now be thrown away.

3.The remainder of the soft part is removed from shell and placed in a preweighed, acid-cleaned, polypropylene 4 oz jar. Once all bodies are in the jar it is reweighed. The jars have all sample information written on both top and side of jar.

7.6.3 For SO: The samples are placed in glass jars that are cleaned by rinsing three times with petroleum ether PE. The rest of items used in dissecting are cleaned in the same manner as the TM dissection. The entire body of the mussel is placed in a preweighed, cleaned glass jar. All forty-five mussels are placed in the same jar. The jar has a taped label which has complete sample information on it. The gonads are included in the SO analysis.

7.6.4 For both SO and TM on the first 15 mussels the shell lengths from end to end are recorded. These shells are set aside in the labeled Ziplock bag and for future reference.

7.6.6 The gametogenic condition of sample is also noted and is recorded as ripe, not ripe, or partial ripe. There are immediate conditons noted as partial to ripe, or not ripe to partal.

7.6.7 All weights, lengths, and gametogenic conditions are recorded on the dissecting information sheets.

7.7 Sample Homogenization

7.7.1 For TM analysis:

The samples are homogenized in the 4 oz polyethylene jars using a Brinkmann Polytron (model PT10-35) equipped with a titanium generator (model PTA 20). The titanium generator is cleaned with Micro solution; rinsed two times with tap water; rinsed three times with deionized water; and once with ASTM Type II water. The tissue is homogenized to a paste-like consistence. No chunks of clearly defined tissue should be left in homogenate. The homogenizer is cleaned in between reps.
All water used for cleaning must be changed in between reps.

7.7.2 For freshwater clams: Dissecting and homogenizing of the samples employs the same procedures used with mussels for SO and for TM except that the entire soft body is dissected (the gonads are not removed).

7.7.3 For SO samples: The Sunbeam food chopper equipped with stainless steel blade is used to homogenized the sample. The basket and blade are scrubbed with Micro and rinsed throughly with tap and deionized water. Then rinsed with MeOH and petroleum ether (PE). The sample is placed in basket and ground for five minutes and returned to glass jar.

7.7.4 For both TM and SO: The homogenized samples may be refrozen at -20^{o} C until analyzed.

9.0 QUALITY CONTROL

9.1 Equipment Blanks: All equipment used in collection and preparation of samples is periodically checked for contamination. Before any new or different equipment is used it must be checked for contamination.

APPENDIX E

TABLE 4-2. Measurement quality objectives for BPTCP indicators. Accuracy requirements are expressed as either maximum allowable percent deviation (%) or absolute difference (± value) from the "true" value; precision requirements are expressed as maximum allowable relative percent difference (RPD) or relative standard deviation (RSD) between two or more replicate measurements. Completeness goals are the percentage of expected results to be obtained successfully.

Indicator/Data Type	Accuracy Requirement	Precision Requirement	Completeness Goal
Sediment/Tissue Contaminant analyses:			
Organics	30%	30%	95%
Inorganics	15%	30%	95%
Water Column Characteristics:			
Dissolved oxygen	± 0.2 ppm	NA	95%
Salinity	± 0.3 ppt	10%	95%
Conductivity	± 0.5uS	2%	95%
pH	± 0.2 units	NA	95%
Temperature	± 0.15 °C	NA	95%
Total suspended solids	± 20NTU	5%	95%

Appendix 6

Sustainable Conservation

Partners in Restoration

Creating Model Incentives and Access for Watershed Restoration

SustainableConservation

Partners in Restoration:

Creating Model Incentives and Access for Watershed Restoration
Grant #95-8694

Final Report to the David and Lucile Packard Foundation

June 4, 1996

Project: Partners in Restoration

Objective: To engage new resources, particularly private landowners, in restoring and enhancing the Salinas and Pajaro watersheds in center California.

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Figures and Appendices

I. Project Focus

Sustainable Conservation joined with its partner, the Watershed Institute (formerly the Watershed Ecology Outreach Program), to develop more opportunities for access to private lands for the purpose of wetlands restoration in the project "Partners in Restoration." Because of the paucity of direct funding for acquisition of sensitive lands, access partnerships with landowners are now a key strategy to promote restoration on private property. Since different classes of landowners often require distinct incentives to motivate them to return portions of their property to wetlands, the project explored and applied a variety of tools. A secondary result of this project has been the opportunity to join federal and state agencies in restoration projects on public lands and to partner with those agencies and their constituencies on restoration projects.

The watershed restoration projects of Sustainable Conservation and the Watershed Institute focus on three major sub-watersheds of the Monterey Bay bioregion of California: the lower Salinas Valley, Pajaro Valley, and the former Ford Ord.

II. Original Project Activities and Goals

The original Sustainable Conservation grant proposal specified three categories of activities for Partners in Restoration. A number of goals were established associated with those activities to serve as the evaluation criteria for the success of the project in the initial year of funding *(Figure 1)*.

Figure 1
Activities, Goals and Accomplishments
Partners in Restoration
January 1, 1995 to May 31, 1996

Activities	Goal(s)	Accomplishments
Develop positive incentives	Develop tools to access private land Prepare model documentation for a mitigation bank	Partnerships with corporations, developers and farmers Potential involvement in Carmel River Lagoon Mitigation Bank
Access to demonstration sites	Secure 2 demonstration sites	9 demonstration sites secured (46 Acres)
Develop a relationship with a lead public agency	Advance restoration goals and access	7 public agency relationships

III. Creating the "Tool Box": Monetary Incentives for Watershed Restoration

Sustainable Conservation conducted research on various incentives with the goal of identifying and customizing specific tools to promote conservation activities in Monterey and Santa Cruz Counties.

1. The research took several forms:

    a. A series of interviews were conducted with local landowners, environmentalists and county planning staff to gauge the potential acceptance of incentives programs, how the different stakeholders defined incentives, barriers to incentives use, and opportunities for on-the-ground implementation of incentives.

    b. Our partner, the Watershed Institute, believed that developing a program that provided property tax credits or forgiveness would be the most effective incentive for local landowners to promote restoration and conservation activities at the county level. Because California does not have such a program, Sustainable Conservation surveyed property tax programs nationwide to search for models. Two property tax credit programs were identified in Maryland that are designed to support conservation planning. Contacts were also made with the California State Board of Equalization, the California State Association of Counties, and a county auditor to determine the potential for implementation of a property tax credit program.

    c. More general research was conducted regarding incentives and alternative financing mechanisms available to promote restoration or to fund the purchase of sensitive resource lands, particularly wetlands. The incentives and alternative financing mechanisms investigated were: property tax credits, income tax deductions, transferable development credits (TDC), mitigation banking, water credit trading, state sponsored conservancies, and benefit assessment districts.

    d. Existing incentives programs were surveyed in Monterey and Santa Cruz County. This was done to determine if there were opportunities to coordinate Sustainable Conservation activities with those of public agencies and to learn how the programs were being received in the two counties.

2. General research findings:

    a. Based upon the interviews conducted with local stakeholders, most specifically landowners, several major issues were identified that would be significant barriers to implementation of incentives programs:

        i. The intent of many landowners, particularly farmers, is to retain the land for production purposes now and in the future. To receive federal and state income tax deductions property owners must generally cede their development rights to the land in perpetuity to receive the deduction. Landowners expressed concern that by ceding development rights they give control of their lands to unknown entities that add another layer of regulatory authority over their property.

ii. There is rampant mistrust among landowners of all levels of government, local to federal. Any government sponsored incentives program would have to overcome this mistrust.

iii. The traditional "carrot" for landowners to participate in incentives is changing. Traditionally, market based programs such as transferable development credits offer developers the opportunity to increase base zoning on a parcel, in exchange the developer pays for set-asides of sensitive lands. In the past decade, planning departments have aggressively sought to encourage further development infill of settled areas and/or to encourage increased densities in home building in order to use existing public infrastructure more efficiently, to manage transportation and to meet federal regulatory standards for air quality. As a result, it is no longer always considered a special consideration to receive approvals for higher base zoning. Developers also report more difficulty selling homes in these areas because market demand is often limited for higher density development.

iv. Landowners consistently complain about the lack of coordination and communication between state and federal resource agencies. Poor coordination and communication can result in inconsistent policy implementation of resource protection programs. This lack of coordination makes many landowners angry and unwilling to voluntarily participate in incentives programs. Linking incentives to "steady-state" regulation, defined as more timely, consistent and coordinated regulation is strongly desired by landowners, especially developers. Added regulatory certainty is often of equal value to a landowner as are the tangible monetary returns traditionally associated with incentives.

v. In addition to incentives, there has to be consideration of disincentives when trying to promote wetlands restoration. Disincentives to conservation primarily stem from existing law and regulation.

For example, landowners fear that allowing wetlands restoration to occur will encourage colonization of their lands by threatened or endangered species. Under Section 9 of the federal Endangered Species Act, "take" of imperiled species is prohibited on private lands. Take is understood to mean acts that harm a species, including habitat modification. Section 9 can set in motion the type of events that have been described as "economic trainwrecks" by Interior Secretary Bruce Babbitt because its provisions have been interpreted by regulators to prohibit activities that modify habitat in ways sufficiently severe as to make likely the death or destruction of a species. The practical effect of such provisions is to place indirect moratoria on otherwise lawful economic activities that may result in harm to threatened or endangered species. Faced with the prospect of economic loss from regulation, property owners fear initiating or engaging in conservation activities.

Different approaches to eliminate regulatory disincentives include: safe-harbor exemptions when listed species colonize protected habitat, take prohibitions tailored to specific land-uses, voluntary consultations with resource agencies for small projects that do not involve federal action, expedited small project permitting, general permits for ongoing operations and maintenance, and assurances that new listings will not invalidate existing conservation agreements.

3. Findings following a review of property tax credit programs and income tax deductions designed to promote conservation and restoration activities:

a. *Property taxes:* Any property tax forgiveness or tax deductions would either have to be approved by the California legislature or agreed to within the different jurisdictional units that receive property taxes. A combination of state budget woes, Proposition 13 and similar propositions that limit the capacity of all levels of government to capture tax revenues make it highly unlikely that the state, counties, cities, or special districts will support legislation that proposes further reductions in property tax revenues, even for public purposes such as conservation of sensitive lands.

Upon collection, the State of California takes a large share of the property taxes. It then distributes the remaining portion to a plethora of special districts, cities and counties. Once the property tax is distributed from the state to the local level, each jurisdictional unit could theoretically agree to allow its portion of the property taxes to be used for conservation purposes or request to be exempted from the program. While there is a precedent for doing this to promote economic development in a region, in many communities it would be a much harder sell for the purpose of acquiring open space or for the purchase of development rights.

b. *Federal income and corporate tax deductions*: Tax deductions provided in return for the gift or purchase of conservation easements are the most familiar incentives used to motivate a landowner. However, conservation easements are most useful where individuals already inclined towards conservation are rewarded. Landowners at the margin may never choose to participate in a program. For example, Monterey and Santa Cruz County participated in a program to purchase easements as a means to preserve farmlands. Despite the availability of several million dollars in funds for the purchase of the development rights for land and the attendant tax benefits, the acceptance of the program was very slow. The market value of farmlands (the price per/acre for high quality farmlands in Monterey County is $20,000 to $30,000) and the lack of desire by farmers to accept limits in perpetuity on land-use, made the program unappealing to many landowners.

c. *SB 1280*: This is a bill recently proposed to promote conservation efforts in California. The bill proposes that property owners who donate land or conservation easements to government or nonprofit organizations for either environmental protection or agricultural preservation receive an income tax deduction for their donation. It also allows these tax deductions to be sold for cash. Under SB 1280, the federal government subsidizes 35 percent of the cost of the credit, since donors of land also receive a federal tax deduction. The bill caps the amount of land which can be contributed annually to $200 million to avoid placing too much demand on California's general fund. It aims to encourage donation of land needed for habitat conservation plans, multiple species conservation plans, wildlife corridors, and water rights needed to conserve fish. Although the bill failed to pass in the 1994-1995 California

Legislative session, a broad range of business and environmental interests have now endorsed it. This should smooth its progress. If passed, we will begin using it in combination with federal tax deductions available for conservation easements to promote restoration on-the-ground.

d. *Estate taxes:* With a $6 billion intergenerational transfer of wealth expected in the next two decades upon settlement of estates, an enormous quantity of land may become available for conservation purposes. Unfortunately, a significant disconnect exists between estate taxation and conservation of large, contiguous blocks of land to provide for habitat and open space. All the problems are known and all the ideas to improve the treatment of estate taxes widely circulated. Currently, if real property is not subject to a conservation easement prior to death, it is not possible for the heirs to an estate to make additional gifts to reduce estate tax liability. As a result, land may have to be sold to pay estate taxes which can result in the subdivision of large properties, an action antithetical to effective conservation strategies. Compounding the problem is that estate tax assessments are based on the highest and best use value of the property -- highest and best use is defined as the value of land when developed as intensively as possible, not its value in terms of actual use. This valuation methodology can result in an onerous tax burden for undeveloped (i.e. agricultural lands) or forested land, forcing the break-up of large, contiguous parcels.

4. <u>A review of other forms of incentives with some potential application to the Partners in Restoration project</u>:

a. *Transferable development credits:* There are two ways a TDC program can be structured. The first way is to have individual landowners voluntarily enter into negotiations where the property owner (the "sender") of open space, agricultural, or habitat land sells or transfers development credits to a landowner-developer (the "receiver") wishing to increase the density on a developable parcel. Local government can encourage such transfers by acting as a facilitator and by allowing an increase in density over the base zoning on the receiver parcel in return for a dedication of a perpetual conservation easement on the sender parcel.

The second means to structure a TDC program is for local government to formally adopt a TDC ordinance to encourage such things as protection of wetlands, while guiding future development into areas most capable of supporting increased density. The TDC ordinance designates by zoning "sender areas" where development is restricted and "receiver areas" where density may be increased. Landowners wishing to develop above the base zoning in the designated receiver areas must acquire TDCs from landowners in the sender areas. When TDCs are sold, the sending parcel must dedicate a perpetual conservation easement over the land which prohibits future subdivision or changes in use.

While Monterey County has successfully implemented a TDC program, it involved a single landowner in the limited geographic area of the Big Sur viewshed. Sustainable Conservation explored potential implementation of a TDC program with two developers that own sensitive lands: Keith Development Company and the Monterey Resources Group; a landowner's representative from the Landmark Real Estate Company; and the Planning Department, Santa

Cruz County. The opportunities for TDC implementation are limited at this time for the following reasons:

- Demand for development in the area;
- Environmental prohibitions against development of land or resources in specific areas;
- The difficulty of implementing a TDC program across jurisdictional boundaries;
- Potential imbalances between landowners of open space as compared to landowners of developable parcels;
- There is not always an exact match between fair market value and development credits.

b. *Mitigation banking:* Mitigation banking is one technique now employed to convert the intangible conservation values stemming from wetlands into a market price. A mitigation bank uses a system where each credit represents a unit of created, restored, enhanced, or preserved wetlands which can be withdrawn or sold to offset impacts incurred at an off-site development. Touted as a means to increase the effectiveness of land-use regulations and to overcome limited public funding for acquisition of sensitive lands, such banks also attempt to facilitate development that is both compatible with conservation objectives and that captures a portion of the development value of wetlands.

From the perspective of a landowner, a mitigation bank can provide multiple returns. There is currently a lack of tangible monetary incentives for the private sector to restore wetlands. Mitigation banking promises to fill that gap. The value of a mitigation bank is that it may also offer more certain, timely and cost-effective permitting than is characteristic of traditional command and control regulation. It can streamline the permit process by providing a supply of credits for developers or public agencies who need and qualify for them.

Until recently, no direct market for wetlands mitigation credits existed in Monterey County or its watersheds. Although there has not been significant development pressure in Monterey County, the demand for credits is also affected by the following issues:

i. *Sequencing:* Since the early 1990s, the regulatory agencies have used a three-step sequencing process that requires impact avoidance, minimization and finally, compensation for unavoidable impacts. Prior to receiving authorization to purchase or use off-site mitigation credits, all appropriate and practical steps must be undertaken by a project sponsor to first avoid, then minimize adverse impacts on the wetlands found on-site. While sequencing is a reasonable precondition to all forms of compensatory mitigation, it can limit the circumstances when a developer or a public agency can use mitigation credits.

ii. *Geographic scope:* The primary goal of mitigation banking is to fully compensate for wetland and other aquatic resource losses in the particular watershed or county where the project(s) impact occurs. A general rule-of-thumb used to define the geographic service area of a mitigation bank is 40 miles. There has to be development pressure in the geographic service area of the mitigation bank to provide for this type of demand or there is no demand for credits.

iii. *In-kind mitigation:* The strict definition of in-kind mitigation requires replacement of converted wetlands with wetlands of the same type. In-kind mitigation is usually preferred by the agencies in the interest of achieving functional replacement. Where there are development pressures, there are not always parallel opportunities for in-kind mitigation. The location of development in a particular area may limit the market for in-kind mitigation. For example, if most development in an area effects oak woodland habitat, there will not be the opportunity to mitigate using a wetlands credit.

c. *A new market for mitigation credits in Monterey County*: As a result of the need to mitigate adverse project impacts from construction of a new access road to the Carmel Area Wastewater Treatment Plant, removal of levee segments near Highway One, construction of a new bridge on Highway One, and for future highway improvement projects, the Wastewater District, Caltrans, and the California Parks and Recreation Department have plans to establish a mitigation bank within the Carmel River State Beach. Phase II of the project involves revegetation, restoration and enhancement of habitat in the area. The Watershed is now developing a proposal for Caltrans to develop and implement the restoration and enhancement activities in phase II.

d. *Water credits:* Water credits can be used to encourage either water quantity or water quality management. Both issues are areas of concern in Monterey County. Water quantity and quality in the region have been severely compromised by groundwater overpumping and the resultant saltwater intrusion. The Castroville area is now experiencing the most serious saltwater intrusion in the state with 100% overdraft of the major aquifers (*Figure 2 and Appendix I)*. The depletion of the water table has a secondary effect on the health of wetlands in the watershed.

Water quantity control, however, is still evolving as a potential area of concern. Experts believe water trading will play an increasing role in how and when water is used, especially in the arid western states *(Appendix II)*. As we move into an era of diminishing supplies, trading will increasingly play a role in moving water to the highest value uses. Restoration of wetland habitats is a very important, and still relatively unrecognized, component of that future market. Wetlands can increase the volume and residence time of water on the land, permitting greater groundwater recharge. (Water flows most rapidly in layers of sand and gravel and more slowly in layers of peat, clay and dry silt deposits). This adds to existing water supplies and will, in the future, increase the market value of restoring natural lands.

More accurate information about the value of water is crucial to gaining the benefit of market forces. When, for example, a farmer can compare the loss of productive agricultural lands to the gain in water supplies for their own use or for sale, it will be easier to promote restoration of wetlands. Once again, experts believe that in the long-term multiple farmers will bundle and package water rights.

Despite these trends, the use of water credits it is not likely to occur in Monterey County in the immediate future. One real inhibitor to developing a market for water credits is that people fear losing their rights to that water. Additionally, extraction of groundwater is not currently regulated in the water district. This leaves little reason for landowners to participate in a credit program.

Until the time there is a change in the treatment of water rights in California and in this specific water district, this is not fruitful ground for application of incentives on a regional basis. However, some change in policy is now being contemplated by the Monterey County Water Resources Agency in a new Basin Management Plan that may involve gauging wells. Additionally, in cases where individual farmers have experienced water shortages, they are more attentive to the value of wetlands restoration that can increase the amount of water on their land.

5. A review of alternative financing mechanisms for acquisition of sensitive resources lands as models for potential application to the Partners in Restoration project:

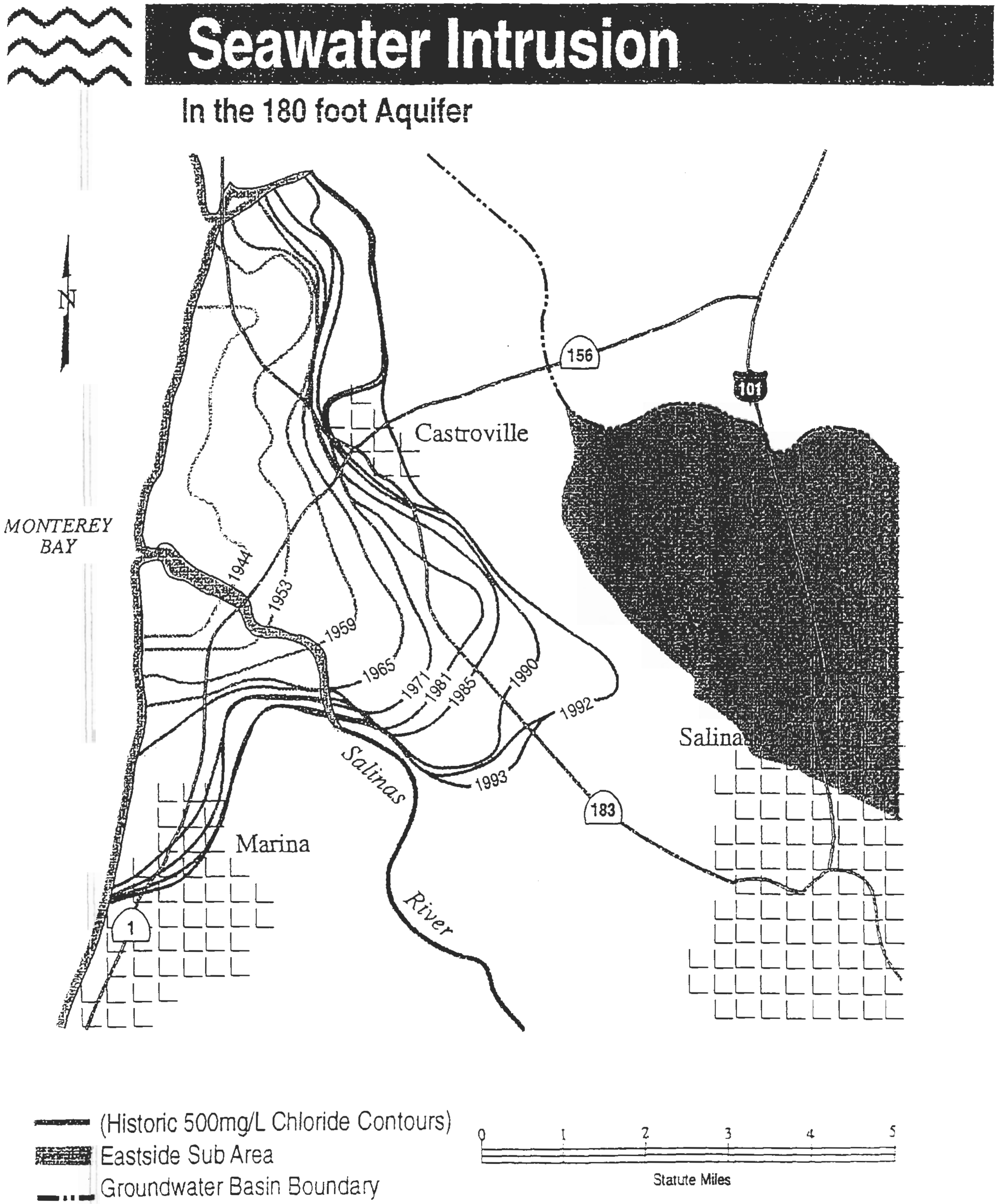
a. *Conservancies:* Several state agencies were established by the California legislature to preserve lands of unique ecological value including the Santa Monica Mountains Conservancy and the Tahoe Conservancy. Following designation as conservancies, general fund moneys, staffing and acquisition moneys are dedicated to this purpose. In the current budget environment, however, a condition for getting the most recent conservancy approved was that it would not receive state general fund dollars for its operations. Consequently, there is no money to hire staff or to acquire lands. All moneys committed to the conservancies are discretionary. This limits the potential of a conservancy to focus conservation priorities and to offer programs.

b. *Benefit assessment districts:* Under California law (the Mello-Roos Act), any city, county, joint powers authority, or other municipal entity may establish a community facilities district to finance acquisition or construction of facilities that are necessary due to growth and development. A special or benefit assessment is based on a formula that assigns different tax rates to parcels according to a calculation of benefit. For example, additional assessments specifically designed to fund open space acquisition may be levied on property owners. This is done by making a fixed benefit assessment per parcel or home. The original benefit assessment district was approved in 1992 by Los Angeles voters to fund facilities improvements including streets and lights. Included in that program was a provision to fund acquisition of open space.

Because of the scramble for additional tax revenues, proposed benefit assessment districts have faced increasing resistance from voters since passage of that first district in Los Angeles. Voters have become disenchanted with efforts to impose additional fees for specified infrastructure or programs. For example, when San Francisco recently attempted to develop a benefit assessment for parks and recreational facilities, it was roundly criticized for the effort. A taxpayers group in Monterey County rigorously tracks such programs. Given the current environment, it seemed unlikely that such a proposition would pass in Monterey County.

c. *State Funds — The Wildlife Conservation Board:* The mandate of the Wildlife Conservation Board (WCB), a state agency, is to acquire lands to protect and conserve the

Figure 2: Seawater Intrusion into the major Aquifers



biotic diversity of California. After determining that the landowner would only be interested in an acquisition of the lands, Sustainable Conservation approached the WCB with a proposal to acquire sensitive habitat lands along the Moro Cojo Slough in Fall 1996. Details concerning this proposal are provided in the Section VII of this report describing the Moon Glow Marsh owned by the Granite Rock Company.

IV. Creating the "Tool Box": Non-monetary Incentives for Watershed Restoration

A key finding in this project was the significant role that non-monetary incentives can play in gaining access to private property for purposes of restoration. Relative to most monetary incentives, non-monetary incentives are easier to implement. This is because they are not generally distributed through traditional institutional structures and governmental agencies, where bureaucracy is at it maximum and landowner trust is at its minimum.

1. Key non-monetary incentives used to gain access to private property:

a. *Compliance with existing law and regulation:* To a certain extent the need to protect wetlands is established in federal, state and local statutes including: the Clean Water Act, the California Coastal Act, the state and federal Endangered Species Acts, and in general plans, local coastal plans, and specific plans developed for the region and community. Using both existing statute and zoning, Sustainable Conservation sought to develop ways to fulfill the purposes and requirements of the regulations, while finding strategies for the landowner to reap some economic return from their lands when limited by statute. To the extent that compliance is facilitated, landowner cooperation and resources dedicated to restoration are maximized.

b. *Attaching tangible "human" or economic values to wetlands restoration*: In many cases, there are human or economic values that come with wetlands restoration. The foremost values for a landowner are:

i. *Water quality*: In 1996, the Environmental Protection Agency found that nitrate contamination is the most pressing water pollution problem effecting the Salinas River and Valley. Restored wetlands provide surface water filtration, purification, and storage capacity, and are a very cost-effective way to deal with non-point source pollution as compared to treatment facilities or pipes.

ii. *Water quantity*: As discussed, northern Monterey County is now experiencing some of the most serious saltwater intrusion in the state with 100% overdraft in some of its major aquifers. Restoration of wetland habitats helps reduce saltwater intrusion by increasing the volume and residence time of water on the land, thus permitting greater groundwater recharge.

Both values closely parallel the Water Management Initiative developed by the California Water Quality Control Board. Under this Initiative, wetlands in a particular watershed are designated as water quality management areas and natural systems are restored to provide for filtration and groundwater recharge.

iii. *Flood control:* Two disastrous flood seasons in Monterey County have refocused attention on the value of restoring wetlands to increase the water storage capacity of lands during floods.

iv. *Regulatory certainty:* By avoiding sensitive lands or engaging in proactive conservation or restoration, developers can make the process of gaining regulatory approvals more timely, certain and cost effective.

v. *Technical and scientific support:* Where possible, Sustainable Conservation worked with Watershed Institute scientists to assist landowners to evaluate the resources on their lands and to develop low cost or no cost restoration and management plans and implementation activities. In some cases, they would also meet with the regulators and landowners to find solutions to resource conflicts that established common ground between conservation and economic goals.

vi. *Maximizing value of marginally productive property:* The most effective use of conservation easements occurs when a landowner owns a marginal parcel of land in terms of economic use, but where sensitive resources occur. Such lands might include those with limited agricultural productivity or development potential. Marginal property would be defined as lands with poor soil, a lack of water or no links to sewage treatment facilities. They would also be defined as property where their economic use is limited by statute or where regulatory exactions are attached to development.

vii. *Corporate goodwill:* Creating goodwill in the communities in which they operate often creates economic value for corporations.

2. Other non-monetary tools:

In addition to the incentives themselves, their are other tools that make the implementation of restoration on private property more accessible. These include:

i. *Coordination:* Where needed, Sustainable Conservation helps coordinate communication between the landowner and the different public agencies with an interest in or regulatory mandate over a wetland.

ii. *Knowledge:* A working knowledge of the economics of development and agriculture, the marketplace, planning, law, and biology are necessary to develop solutions to complex land-use challenges. Sustainable Conservation was able to draw on various resources to help synthesize this information to find those solutions.

iii. *Verification:* Commitments to protect wildlife and habitat in return for incentives must be verifiable and enforceable. Sustainable Conservation worked closely with Watershed

Institute scientists to provide public agencies and landowners with ideas that provided this link.

iv. *Trust:* Invoking the concept of trust may sound like a Pollyanna concept, but it is impossible to overstate the need to address the psychological issue of trust to landowners. It takes some time, but building trust is the single most important issue to the success of any type of incentives program.

V. Tailoring Access Strategies for Different Types of Landowners

"If you don't have the right materials, you can't make a basket."
Linda Ynane, Rumsien Ohlone tribe, Carmel Valley

One of the partners in the Watershed Institute is a program where local and regional Native American tribes propagate native plants used for making traditional baskets as well as for food and medicinal purposes. A local basket maker commenting on what makes something valuable to another said "it is the right materials." She went on to say that these materials are not always easy to locate on the shelf of a store. You had to go out and find them.

It is with this wise sensibility Sustainable Conservation approached and developed its access strategy. The most important structural material is partnership. We complete our basket with a wide range of materials that are valuable to each individual landowner. Because of the needs of different landowners, it is unlikely that any single incentive will be valuable to everyone. With each landowner contact, Sustainable Conservation had to be prepared to combine and tailor techniques to respond to the different landowner perceptions of value.

The centerpiece of Sustainable Conservation's strategy involves tailoring the incentives and tools described in Sections III and IV to the needs of three types of partners:

1. *Corporate partnerships*: Our strategy is to appeal to their desire to develop community goodwill, describe the mitigation potential of restoration, assist with regulatory coordination, provide technical information, and respond to corporate inaction in cases where the land is vacant. In the last circumstance, presenting creative options for use of the land is often of significant interest to a corporation. This would include using the lands for mitigation or the potential use of land for water credits.

2. *Developer partnerships:* Our strategy is to encourage developers to engage in proactive conservation or restoration to improve regulatory certainty, describe the mitigation potential of restoration, assist with regulatory coordination, provide scientific or technical information, and provide information regarding tax incentives available for conservation.

3. *Agricultural partnerships*: Our strategy is to present the values of wetlands restoration, with focus on water quantity and quality improvements and flood control, assist with regulatory coordination, provide scientific and technical information, and build trust and respect. We work from the premise that all restoration will involve are simple changes in

management practices (i.e. fencing) within their control and without a significant impact on their profits. We try to understand individual property agricultural operations to find common ground between the need of the farmer to remain productive/profitable and restoration goals. This informational exchange is a two-way street. Long-standing neighbor-to-neighbor relationships are very important to the agricultural community and are a key component of this strategy.

Figure 3
Types of Partnerships and Access Strategies
Partners in Restoration

Types of Partnerships	Incentives	Application
Corporations	• Goodwill • Mitigation • Regulatory Coordination • Technical Information • Acquisition	• Pacific Gas and Electric • Catellus Development Corporation (identified as the Southern Pacific Railroad property in the original proposal to the Packard Foundation) • Granite Rock
Developers	• Regulatory Certainty • Mitigation • Regulatory Coordination • Technical Information	• Moss Landing Heritage Center • Elkhorn Slough Foundation East • CHISPA • Chapin Development* • Tai Associates*
Farmers	• Water Quantity • Water Quality • Flood Control • Regulatory Coordination • Technical Information	• Coke Farm • Salazar Farm • Moon Glow Dairy*
All landowners	• Coordination • Knowledge • Verification • Trust	*A sampling of existing restoration sites where strategies have previously been applied

VI. Implementing the "Tool Box": Nine Restoration Demonstration Projects

The most tangible result of the work of Sustainable Conservation and the Watershed Institute is exemplified by the demonstration sites accessed and restored over the course of a year. To date we have achieved access on a total of 46 wetland acres, on nine different properties, that are now being restored or will be the focus of restoration efforts in 1996.

1. Demonstration Site #1: The Moss Landing Heritage Center:

   This one acre freshwater wetland is located in Moss Landing. Access to the parcel was gained following discussions with a limited partnership involved in the development of a potential commercial/visitor serving facility on the site. The key incentive for the landowner was to ease the general permitting process by engaging in voluntary environmental enhancements in advance of regulatory mandates. Restoration of the site involves weed and exotic vegetation control. The land is also being plumbed to bring water into the low area with the goal of creating a freshwater pond *(Figure 4)*.

2. Demonstration Site #2: Elkhorn Slough Foundation East:

   This 16 acre wetland site is located adjacent to the proposed Moss Landing Heritage Center development project. Restoration access was gained by piggybacking preservation of this area with the advance mitigation strategy developed for the Heritage Center. The landowners were also motivated by the tax deductions available when land was placed in a conservation easement. This strategy was appealing because the acreage had limited development potential stemming from its location in the Coastal Zone. Current restoration activities involve weed and exotic vegetation control. Future plans involve linking this parcel to the other restoration efforts in the Moss Landing area, including the Pacific Gas & Electric site. Using water from the Castroville Slough, a series of freshwater ponds will eventually be created with associated wetland vegetation types *(Figure 5)*.

3. Demonstration Site #3, Jimenez:

   This two acre wetland is located on the Castroville Slough. The landowner agreed to access after learning about the flood control benefits of wetlands restoration. The acreage is also located in a low area just below the Chapin site, an existing restoration project. Although the restoration has not yet started, it will eventually involve exotic vegetation removal, planting small riparian trees, and ponding of freshwater.

4. Demonstration Site #4, Guerrero:

   This one acre wetland is located in the Prunedale Hills. The homeowner was interested in restoration to improve aesthetic and resource values on the site. A former chicken ranch, the land was seriously degraded. Restoration involves decommissioning a ditch and exotic vegetation control. A small riparian corridor was planted and a freshwater pond added to the site. It is an excellent example of wetlands system rehabilitation that involves reducing degradation, coupled with active restoration and enhancement to recreate displaced functions. The site should be a flourishing wetland in four to five years *(Figure 6)*.

5. Demonstration Site #5, Coke Farms:

This five acre wetland is located in the Pajaro River Watershed. The land is owned by an organic vegetable and strawberry farmer. A conservation easement held by the California Department of Fish and Game (CDFG) limited its use for farming, although there was no current restoration or management of the sensitive resources. The farmer agreed to exercise the nascent conservation easement when presented with the opportunity to improve resource values on this vacant site at no cost *(Figure 7)*.

Ecologists from the Watershed Institute worked in concert with the CDFG to develop a restoration plan. Restoration of the site involves planting riparian trees. The trees improve resource values and act as a wind break to soil erosion on the farm. The farm is located in the part of the watershed that experienced severe flooding in 1995. Restoration may also contribute to flood control.

6. Demonstration Site #6, United States Fish and Wildlife Service (USFWS), Salinas River Restoration:

This 200 meter section of historic riparian forest is located along the south bank of the Salinas River. Prior to contact with Sustainable Conservation, the United States Fish and Wildlife Service was not very active in Monterey County because of funding and staffing limitations. The incentive for the agency was to gain a partner in the region that would take direct responsibility for restoring a neglected resource. Partnering with the Watershed Institute will also help the USFWS achieve its long-term goal of developing high quality wildlife habitat in the area.

This land was formerly a continuous and complex riparian forest along the Salinas River extending to the ocean. Only a remnant of that original forest is still intact along the last mile of the river. The restoration plan involves planting riparian vegetation to stabilize the riverbank and to reestablish wildlife habitat. The USFWS gave the Watershed Institute a $10,000 grant to fund the restoration.

7. Demonstration Site #7, Salazar Farm:

This 3 acre wetland is located adjacent to the Elkhorn Slough on a strawberry farm. The farmer agreed to allow his lands to be used as a pilot site to demonstrate the value of flood and erosion control stemming from restoration of wetlands, following a meeting spearheaded by Sustainable Conservation and the Natural Resources Conservation Service (NRCS), an agency of the United States Department of Agriculture. The farmer will enroll in a NRCS program that finances erosion control measures on steep slopes. A representative from the California Department of Fish and Game also participated in the meeting to discuss the

Figure 4: Moss Landing Heritage Center

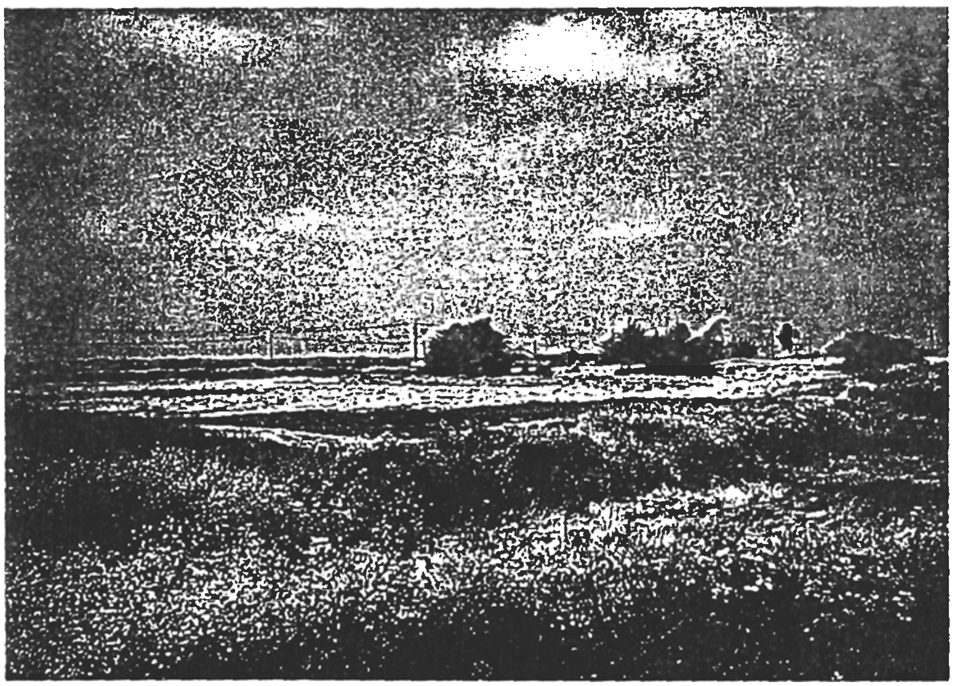


Figure 5: Elkhorn Slough Foundation East

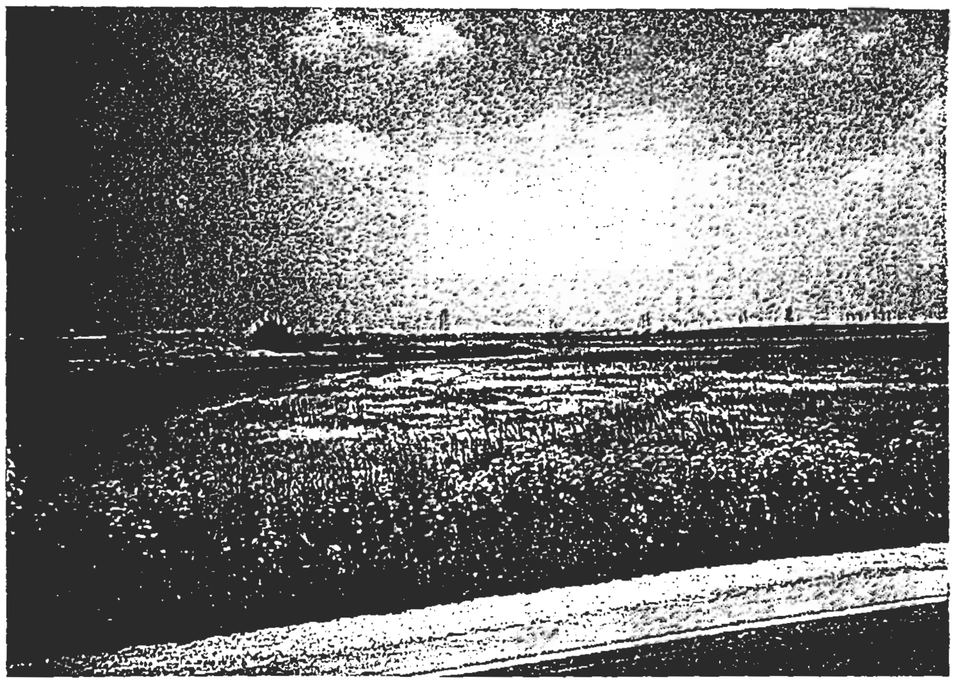
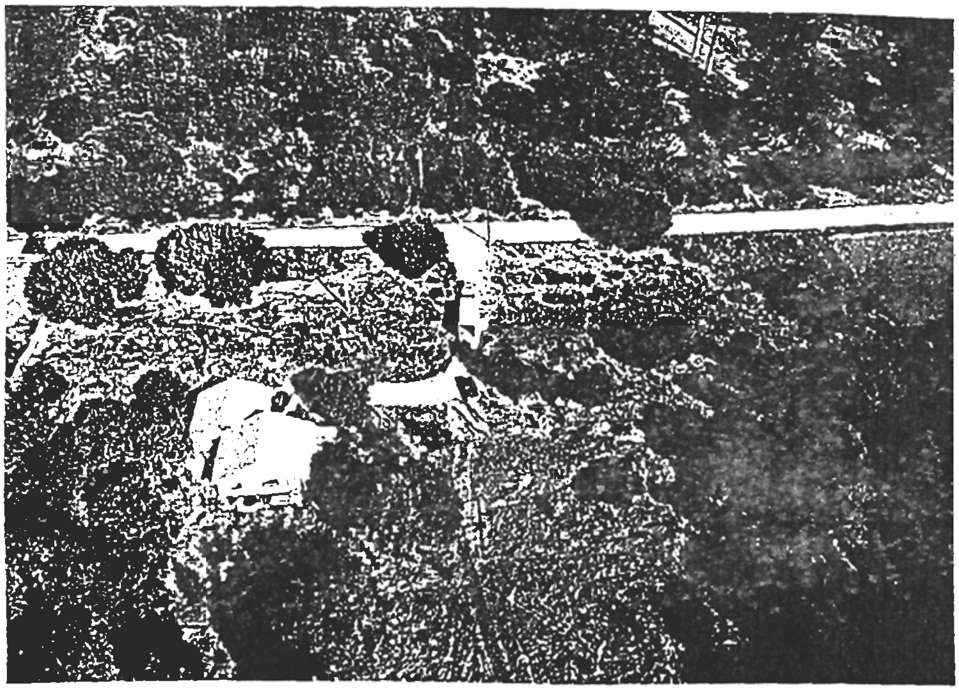


Figure 6: Guerrero Site (formerly degraded poultry farm)



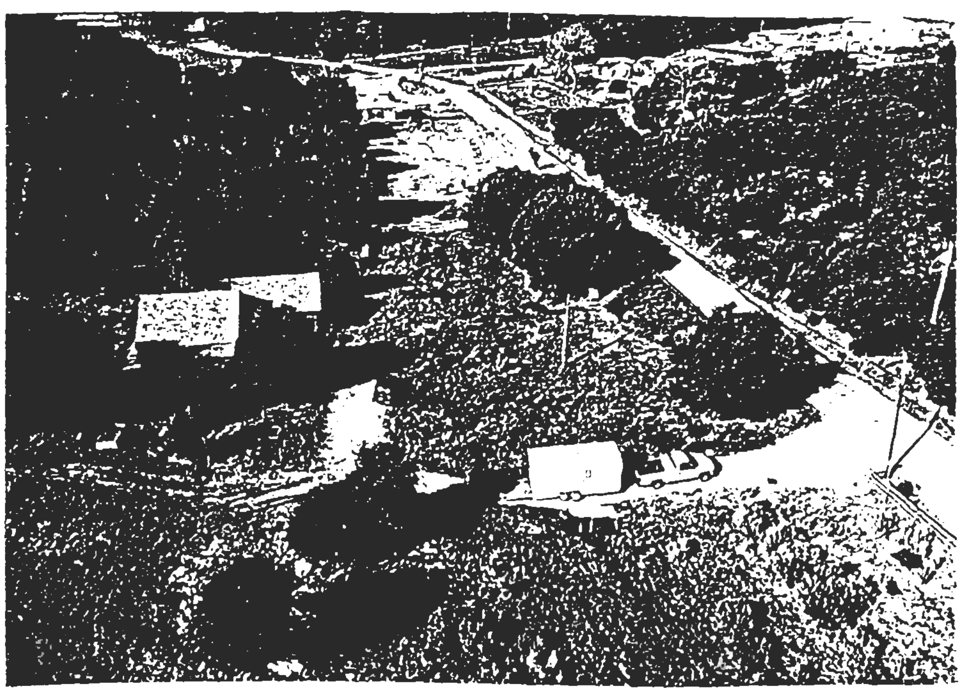


Figure 7: Coke Farm

farmer's concerns with the implications of any future colonization of the wetland by threatened and endangered species.

The NRCS will survey the parcel and provide a map of the site to develop the overall plan for the farm. The farmer offered to provide the earthmoving equipment. The California Department of Fish and Game will identify the invasive non-native plants on the site, offer suggestions for exotic vegetation control, and help select plants for the restoration. Restoration will involve erosion control, removal of sediments from the wetland area, establishment of sediment collection basins, creation of an agricultural buffer zone, and enhancement of the wetland area.

Salazar Farm is an excellent example of the consensus-based public/private problem solving that is a hallmark of Sustainable Conservation and Watershed Institute activities.

8. Demonstration Site #8, North County High School:

This 7 acre wetland is located adjacent to the Moro Cojo Slough in the upper watershed and in close proximity to Castroville, Oak Hills and Monte Del Largo. At the time the Community Learning Center was developed the Coastal Commission recommended that a condition for approval of the development permit should be that a resource-based environmental education program be coupled with wetlands restoration to best manage the sensitive resources on the site. North Monterey County Unified School District officials indicated that it was their objective to instruct students in ecology and environmental sciences based on the school's location. Unfortunately changes in faculty and shortfalls in funding for education have prevented the school from developing such a program.

The wetlands are degraded at the school. Campus-wide there are also few environmental aesthetics and a minimum of landscaping. When the development plan was approved for the school, the Coastal Commission expressed concern that there would be increased pollution, sedimentation and erosion into the Moro Cojo Slough drainage way.

Following a meeting with Sustainable Conservation staff, science faculty are ready to enthusiastically support restoration of the wetlands on campus. While the school still lacks resources for a fully developed environmental education program, students will be informally involved in wetlands restoration, monitoring and maintenance activities. Tentatively slated to start in Fall 1996, restoration of the wetlands will immediately improve campus aesthetics and later reduce detrimental run-off into the Slough. The campus is located within the planning area of the Moro Cojo Enhancement Plan developed by the Coastal Conservancy. Advance restoration of the site may make it a more viable candidate for implementation funding from the Conservancy associated with this Plan.

9. Demonstration Site #9, The Pacific Gas and Electric Company:

This 9.8 acre wetland is located at the Pacific Gas and Electric plant along Dolan Road in Moss Landing. Found at the headwaters of the Moro Cojo Slough, the PG&E lands are one key component of the wider Watershed Institute restoration strategy for this watershed *(Figure 8)*. The site is under transmission towers owned and maintained by the plant. After lengthy negotiations, PG&E agreed to permit restoration as a gesture of corporate goodwill to the community.

Contiguous to the PG&E lands is another pre-existing restoration site, the Moon Glow Dairy operation. Integrating restoration of the two sites has already begun to contribute to resolving some very pressing problems in this region.

As discussed, the Castroville area is now experiencing a serious saltwater intrusion problem in its major aquifers. Restoration of wetland habitats, like the PG&E land and the Moon Glow Dairy, helps reduce that intrusion.

The Moon Glow Dairy is a source of some nitrate rich run-off. Restoration of the PG&E land and the Moon Glow Dairy are now integrated to provide for surface water filtration and purification. Establishing a wetland plant community has already contributed to water quality by providing biological filtration of the run-off. Periodic monitoring of water quality has recently been started as a means to track the effectiveness of the project. Even in the short-term and from a limited data set, improvements in the turbidity (the amount of suspended solids in the water) have been observed in the lower restoration area of the two sites *(Appendix V)*.

During the 1995 floods, historic wetlands in the Moro Cojo Slough kept Dolan Road from being flooded. Restoration of the PG&E wetlands adjacent to Dolan Road will further improve the storage capacity of the land in this area for this purpose.

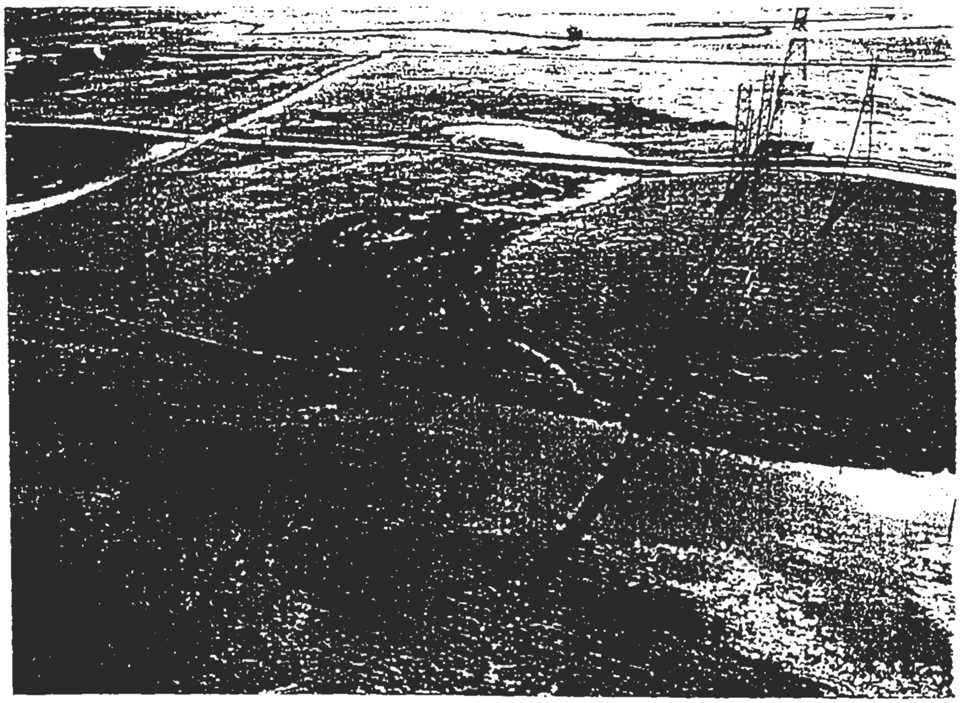
The restoration plan involves impounding winter rainfall and run-off behind shallow hay dams and planting a matrix of annual and perennial native plants. With the cooperation of another adjacent landowner, Sea Mist Farms, the site has been fenced to control cattle grazing in the wetland area.

10. <u>Natividad Creek Park</u>:

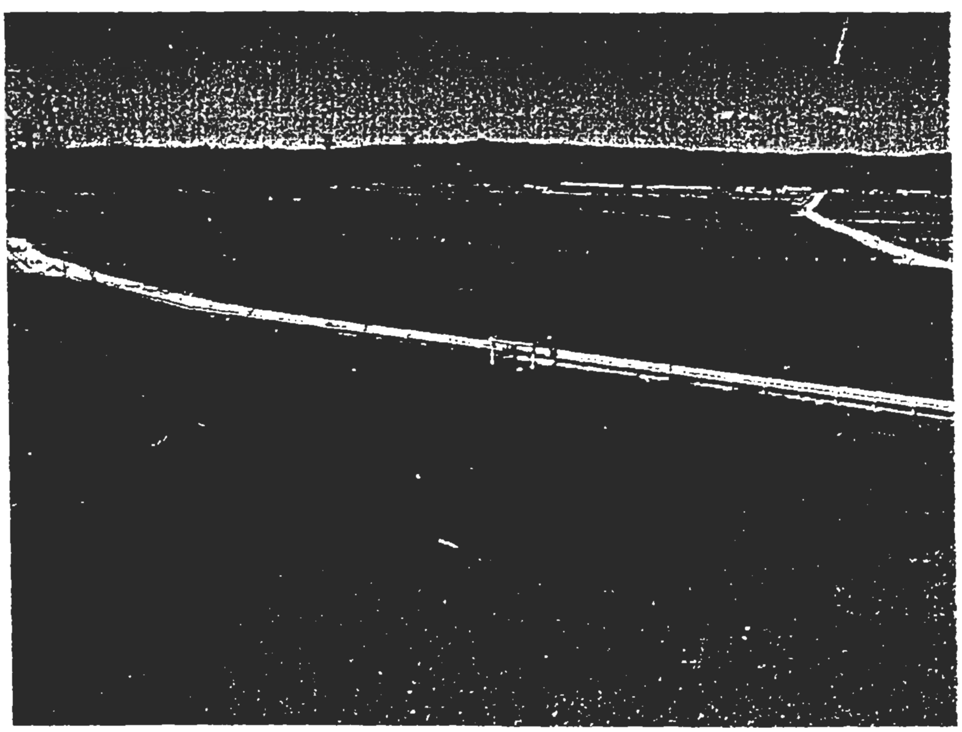
Although not technically a site accessed during the period of the Packard grant, Natividad Creek Park now hosts flourishing wetlands. It is an example of the many long-term values provided by wetlands restoration to Monterey County including: improved community aesthetics, biotic diversity, water quality, and flood control. This 10 acre wetland is located at Natividad Creek Park in the City of Salinas. The restoration program operates under a contract with the Salinas Parks and Recreation Department funded by a grant from the California Resources Agency *(Figure 9)*.

The restoration involved expansion of Natividad Creek from a 10-15 foot drainage ditch into a natural river and wetland system over 200 feet wide. Approximately 1,000 bales of hay were used to stabilize eroding sediment and create shallow ponds for plants and wildlife.

Figure 8: Pacific Gas and Electric

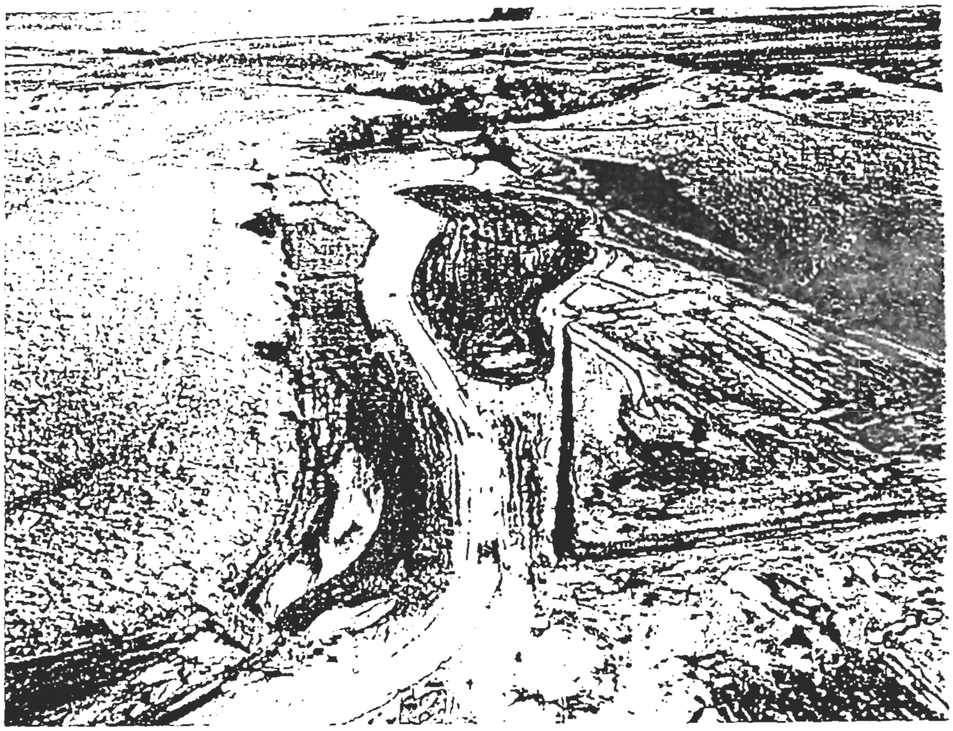


Pacific Gas and Electric restoration, October 1995. Area under transmission towers.

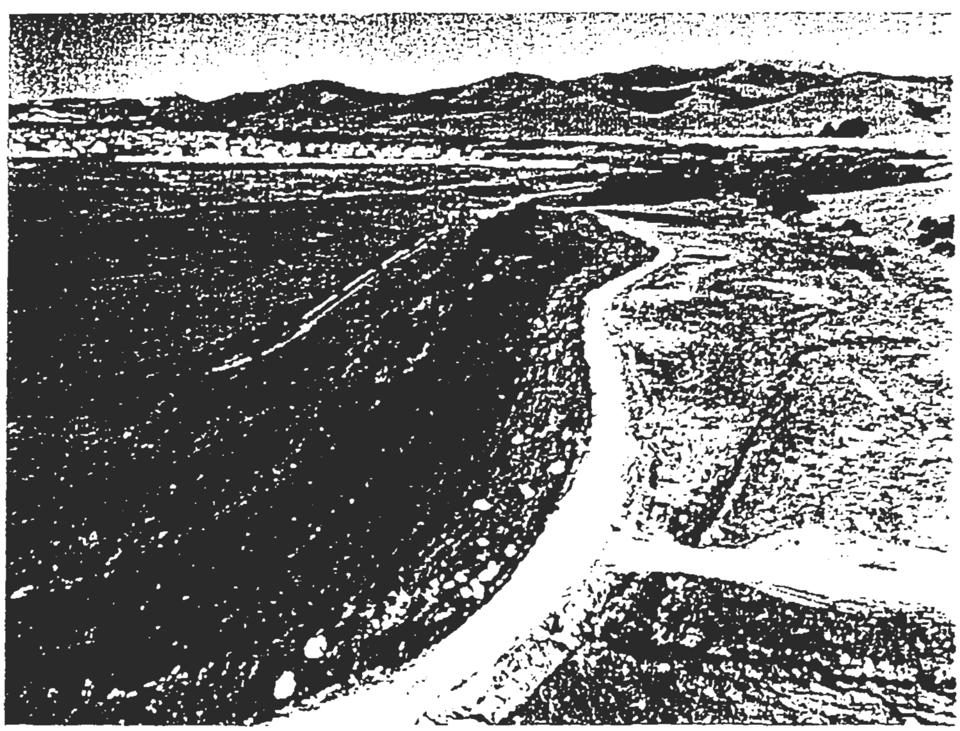


Pacific Gas and Electric restoration, March 1996. After excluding cattle with fencing. Note green area under transmission towers.

Figure 9: The Natividad Creek Park



Natividad Creek, looking upstream, January 1995, during the first year of restoration. Hay bales and ponded water indicate first stages of restoration.



Natividad Creek, March 1996, following one year of restoration with a dense cover of native plants.

Thousands of willow and cottonwood cuttings surround hay berms initiating the ecological process of slowing and holding-water.

The site is the center of plant propagation and restoration activities for the Return of the Natives (RON) program. In the RON program, teachers and students work from the ground up, planning, creating and caring for native plant greenhouses that eventually are used to landscape school campuses and community parks. More than 100 teachers have been trained by the program. Restoration sites, including Natividad Creek Park, become outdoor classrooms where students can learn about plants and ecosystems. Last year, students, kindergarten through college age, and members of the community were involved in the restoration of Natividad Creek Park. These volunteers, about 4,000 in all, grew native plants and helped on several community planting days. Over the summer of 1995, high school students county-wide helped build six greenhouses at the Boronda, Sherwood, Virginia Rocca Barton, Los Padres, Frank Paul, and Alisal schools. Each school is charged with growing 3,000 plants each for the Park *(Appendix III)*.

At the finish of the restoration phase of the park project, $50,000 was trimmed from the original $160,000 state grant. Delivery of the project on-time and at a reduced cost was lauded across the community*(Appendix IV)*. Following approval by the Salinas City Council, this windfall will be applied to develop a richer educational component to the restoration including a trail system that highlights different habitat-types represented in the park and signage keyed to those habitats. During a recent visit to Natividad Creek Park, RON staff reported the return of organisms associated with wetland aquatic habitats, including crayfish, tadpoles and frogs, previously missing from Natividad Creek.

VII. Next Steps: Evolving Access Opportunities and New Relationships

While we are proud of our achievements in Phase I of Partners in Restoration, the fun has just begun! The research and network of relationships developed in the past year have put Sustainable Conservation at the verge of gaining access to approximately 200-300 acres of corporate and private property.

In addition to the PG&E site described above, two other priority sites were targeted for access and restoration in the original grant request to the Packard Foundation. Efforts to secure the parcel owned by Granite Rock and the land formerly owned by the Southern Pacific Railroad are at a very advanced stage.

1. <u>The Granite Rock Parcel, "Moon Glow Marsh"</u>:

   This 23.5 acre parcel is comprised of both wetland and upland habitat and located at the most western tributary of the north side of the Moro Cojo Slough. Owned by the Granite Rock Company, the land is known as the Moon Glow Marsh.

   Following numerous meetings with representatives of Granite Rock Company, Sustainable Conservation determined that the only means to gain access for restoration would be through direct acquisition of the land. Because of the potential significance of the land as freshwater habitat for birds, amphibians and reptiles including a number of threatened and endangered species, a proposal was developed for acquisition of the property by the Wildlife Conservation Board. As described in Section III, the WCB acquires significant habitat lands to protect, conserve, enhance, and restore California's biotic diversity.

In fall 1995, at the request of Sustainable Conservation, John Schmidt, Executive Director, WCB visited the site. Shortly afterward, a Land Acquisition Evaluation (LAE) was developed for the site. The proposal languished then for a number of months. After numerous calls and correspondence regarding the resource value of the site, a biologist from the California Department of Fish and Game will visit the site the first week of June to confirm the original LAE. This information will then be circulated in a special individual proposal to the senior level staff who consider WCB acquisitions from the California Department of Fish and Game. If Moon Glow Marsh is recommended for acquisition, the full WCB will approve or deny the acquisition in Fall 1996.

Scientists from the new California State University (CSU)-Monterey Bay and Moss Landing Marine Laboratory have already agreed to be responsible for perpetual oversight and management of the land. CSU-Monterey Bay has agreed to hold title to the land and plans to model the site after the Jasper Ridge biodiversity research area at Stanford University. The Earth Systems Science Department at the University will provide student-scientists to work on creation, enhancement, and restoration projects for college credit. These students will be mentored by the faculty and associate researchers at the University. The faculty and associate researchers bring expertise in a wide range of watershed fields to this project including hydrology, engineering, chemistry, and ecology.

The research will complement existing Watershed Institute programs, including restoration currently being conducted at the PG&E site described in Section VI of this report. The emphasis of the research effort in ecological restoration will be to provide sound scientific information through hypothesis testing and to guide the reversal of ecological impoverishment. System rehabilitation will involve reduction in degradation, coupled with active restoration and enhancement to recreate displaced wetland functions.

A restoration plan for the site has already been developed and involves planting of a riparian forest including arroyo, yellow and red willow, alder, cottonwood, elderberry and creekside dogwood. The central marsh and pond will be covered with several species of rush. The upland buffer habitat will be planted with creeping wild rye grass, salt grass, sedge, blackberry and a wide variety of wetland associates such as Pacific silverweed and alkali heath. The upland portions of the site will be planted with oak trees, coyote bush, lupines, and tarweeds.

Sustainable Conservation was able to develop broad public support for the acquisition from: Louis Calcagno, Commissioner, California Coastal Commission, Henry Mello, California State Senate, Bruce McPherson, California State Assembly, and Judy Pennycook, Supervisor, Monterey County. Jackie Schaefer, Director, Department of Fish and Game has also provided a written endorsement of the acquisition.

2. The "former" Southern Pacific Railroad parcel now owned by Catellus Development Corporation:

This 195 acre parcel of wetlands located at the mouth of Moro Cojo Slough is one of the largest contiguous parcels of wetland frontage along the Slough. A second parcel comprised of 9.75 acres is also being proposed to the landowner for restoration along the Slough.

Inquiries in Fall 1995 regarding the site confirmed the land was for sale. Because of a pending sale, the landowner would not entertain any proposals regarding restoration until January 1996. Following the sale of the portion of the site zoned agricultural to a local farmer, 195 acres of wetlands remained in the hands of the Catellus Development Corporation, a separate real estate development and management company created by the railroad to deal with its diverse land holdings. Catellus is now one of the country's largest publicly-traded real estate companies and one of the largest landowners in California.

At this time, two proposals have been presented and several discussions have been held with the Director of Diverse Holdings at Catellus by Sustainable Conservation. Catellus is very interested in using its sensitive lands to mitigate development project impacts. To date, the primary strategy pursued by Sustainable Conservation and the Watershed Institute has been to evaluate the potential of the land for mitigation in terms of economics, biology, current and projected land-use, and the current regulatory context for mitigation. Catellus is now seriously considering these proposals relative to its larger development and mitigation strategy.

In addition to the Granite Rock and Catellus properties, there are several very viable prospects where significant work has already been accomplished.

3. Sea Mist Farms:

A third proposed demonstration project potentially involves Sea Mist Farms, one of the largest agricultural landowners in Monterey County. The Sea Mist partnership owns lands along the Moro Cojo Slough, Tembladera Slough, and in Castroville. All these lands are within the Coastal Zone and adjacent to wetlands and waterways.

The Watershed Institute was able to work with Sea Mist Farms to fence a portion of their land used for grazing cattle located adjacent to the PG&E restoration site. Following recent meetings with the land agent for Sea Mist, Sustainable Conservation was able to interest them in the flood control and water quality benefits associated with wetlands restoration. Sea Mist is interested in providing upwards of 100 acres for restoration for this purpose. However, the entire access strategy hinges on the elimination of regulatory disincentives through development of safe harbor provisions that guarantee the landowner will not be negatively affected by the provisions against take of threatened and endangered species found in the state and federal Endangered Species Act.

To this end, Sustainable Conservation and the Watershed Institute will convene a meeting on July 3, 1996, sponsored by Congressman Sam Farr, regarding developing a safe harbors agreement for Monterey County. There will be participants from the United States Fish and Wildlife Service, the California Department of Fish and Game, the United States Army Corps of Engineers, the Farm Bureau, and the Natural Resources Conservation Service as well as representatives from the Monterey Bay Marine Sanctuary, the Elkhorn Slough Foundation and other environmental groups.

The Undersecretary of the California Resources Department has also been contacted to discuss other types of creative responses to deal with this problem. One idea proposed by Sustainable Conservation and the Watershed Institute is to develop a cooperative agreement to mesh regional conservation planning with the economic concerns of the landowners. The USFWS has been pioneering such agreements with individual developers.

4. The Community Housing Improvement System and Planning Association (CHISPA):

Building upon a relationship with the United States Fish and Wildlife Service, Sustainable Conservation and the Watershed Institute have been key participants in developing a habitat management plan that may be part of a cooperative agreement between the USFWS and the non-profit housing agency the Community Housing Improvement System and Planning Association. CHISPA is developing a low income housing project in the upper Moro Cojo Slough near Castroville. Because of its location on sensitive lands, CHISPA is currently seeking to meet a variety of natural resource protection requirements required by the USFWS. Part of the habitat management plan, a condition of permit approval, will involve enhancement and restoration of approximately 170 acres of wetland, riparian forest, and vernal pools habitat by the Watershed Institute. Sustainable Conservation has a previous working relationship with CHISPA on a project that the James Irvine Foundation funded in 1992.

5. Pacific Gas & Electric II:

This 20 acre wetland is located along the Castroville Slough, between the Catellus Lands and Sea Mist Farms. Although the wetland has been diked, drained and channelized, wetland associated vegetation is still found on the site indicating potential for restoration. At the present time, PG&E has requested an appraisal of the land be prepared by Sustainable Conservation and the Watershed Institute. Using this appraisal, we will propose various restoration and conservation alternatives to the utility.

VIII. Agency Relationships Established to Support Access Goals

The original grant forecast one lead agency relationship would have been established at this juncture. Relationships with seven local, state and federal agencies have been established in the region. Partnerships with the California Department of Fish and Game, the Natural Resources Conservation Service, and the United States Fish and Wildlife Service have resulted in the development of three of the eight restoration sites. Our relationship with the Natural Resources

Conservation Service is fairly new, but has the potential to provide for partnerships on many other farms in the region.

1. The California Coastal Conservancy:

   Although scientists from the Watershed Institute had helped craft the "Moro Cojo Watershed Management Plan" developed by the Conservancy to define sensitive resources and establish restoration goals and priorities for the area, Sustainable Conservation was able to initiate a new alliance with the California Coastal Conservancy.

   This renewed relationship may yield opportunities to pursue restoration projects in Monterey County. At this time, discussions are at an early stage with the Conservancy, and two farm groups, California Artichoke and the Monterey County Historical Land Conservancy, concerning restoration of 30 acres of the Armstrong Ranch. The land is a buffer zone to sensitive dune habitat located near the City of Marina. The Conservancy and the two farm groups each own an undivided interest in the ranch. To date, both the Conservancy and the Historical Land Conservancy have agreed in principle to the idea of restoration on the site.

   Stemming from our relationship with the Coastal Conservancy, Sustainable Conservation was able to help develop the agenda and to present information at the first meeting of the Biodiversity Council in the Monterey bioregion. The Biodiversity Council is a group of senior public officials from state resources agencies. Several important relationships were enhanced following the meeting, particularly with the Natural Resources Conservation Service, an agency of the United States Department of Agriculture.

2. The Natural Resources Conservation Service (NRCS):

   The mission of the NRCS is, in part, to deal with problems of soil erosion on farms. Following the Biodiversity Council meeting, Sustainable Conservation met with representatives of the NRCS to discuss the value of wetlands restoration to achieve the goals of the agency. As described in the previous section of this report concerning demonstration sites, an initial site visit to the Salazar Farm has been now completed to evaluate its potential as a demonstration site for the erosion and flood control value of wetlands restoration. Salazar Farm will be a demonstration site.

   Because farmers are very concerned that imperiled species may colonize restored wetlands and that the regulators will then limit farming operations, a representative of the California Department of Fish and Game has also been invited to participate in the discussions. The long-term outcomes of this meeting and the Salazar Farm demonstration site will be an important model for other potential access partnerships with farmers in the watershed. One outcome will be to determine the needs of farmers for flood and erosion control and to better understand the economics of farming operations. It will also offer Sustainable Conservation an opportunity to provide information to representatives of the farming community regarding the potential value of natural wetlands systems to their operations. Participants will establish the ground rules for the restoration and try to deal with the issue of regulatory disincentives that limit habitat restoration efforts.

3. The California Department of Fish and Game:

Sustainable Conservation and the Watershed Institute work cooperatively with the CDFG at the Coke Farms demonstration site and in partnerships with other agencies. For example, the California Department of Fish and Game participated in the site visit to the farm with representatives of the NRCS. The goal of the visit was to inform the CDFG representative of the goals of the restoration and to discuss with the landowner means to avoid the negative regulatory consequences that could potentially result from any restoration activities.

4. The United States Fish and Wildlife Service:

As described above, Sustainable Conservation developed access to wildlife habitat lands owned and managed by the agency along the Salinas River. It is also working with the agency to develop a habitat management agreement for the non-profit housing agency, Community Housing Improvement System and Planning Association. The CHISPA project is described in more detail in the Section VII of this report.

5. The Planning Department and Planning Commission, Monterey County:

Scott Hennesey, the Sustainable Conservation representative for the Partners in Restoration project in Monterey, was appointed to the Monterey County Planning Commission in 1996. In this very visible role, Scott has the opportunity to interact with a broad constituency of interests and to understand their needs concerning land-uses.

Separate from this appointment, Sustainable Conservation has been able to develop positive relationships with the Planning and Building Inspection Department in Monterey County. This is an important relationship because the Planning Department is the repository of information regarding land-use, and landownership and zoning. All are key data to developing partnerships with landowners. The Planning Department also continues to play an important role in the development of the "Moro Cojo Enhancement Plan" with the California Coastal Conservancy.

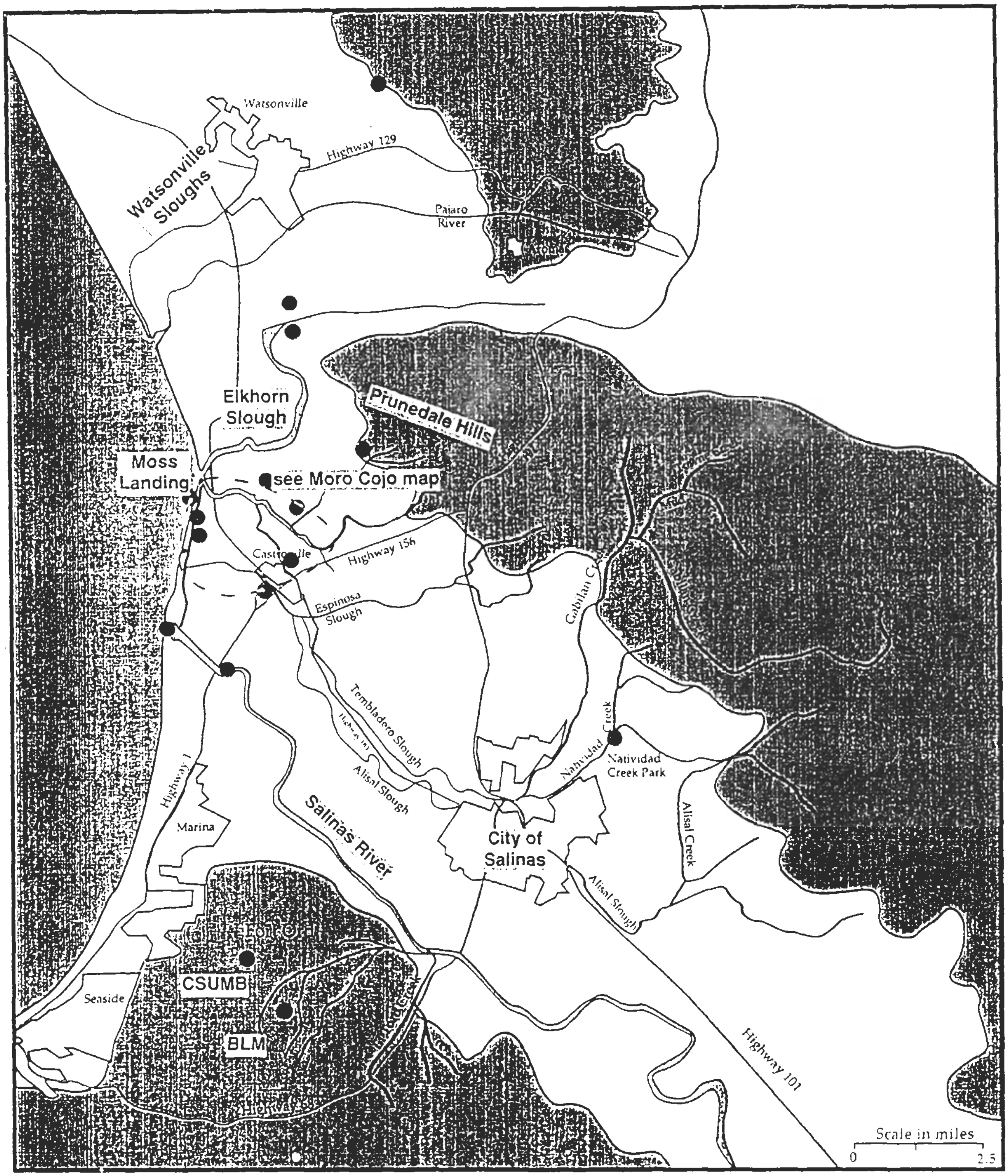
6. The California Coastal Commission:

Most recently, Sustainable Conservation initiated contact with the Coastal Commission regarding the potential restoration site at the North County High School campus and public access at Pebble Beach. Information from the Coastal Commission regarding management of sensitive resources located at the high school helped Sustainable Conservation develop ideas in concert with the faculty for a potential wetlands restoration on campus. Sustainable Conservation also put Coastal Commission staff in contact with the Vice President for Resources Management at Pebble Beach Company to discuss how best to exercise existing public access coastal easements at the resort. Louis Calcagno, a California Coastal Commissioner serves on the Advisory Group for the Watershed Institute.

IX. Conclusion

To date, nine initial freshwater wetlands restoration projects are in progress on approximately 46 acres of land involving corporations, farmers, developers, and public agencies in northern Monterey County. Another 200 to 300 acres could be added to that total in the coming year. These numbers give the best picture of the ongoing success and future opportunities of the Partners in Restoration project *(Figure 10).*

Figure 10: Restoration Sites



Appendix I
North County Water Supply Declining

North County water supply declining

BY CALVIN DEMMON
Herald Staff Writer

The level of water in aquifers under North County is steadily declining, the county Board of Supervisors was told yesterday, while nitrate contamination and seawater intrusion are increasing.

The board got the news in a report from the Monterey County Water Resources Agency, which presented the first part of a detailed study of water issues in the North County area.

The first part of the study took a look at the resources. The second part, to be presented in May, will offer programs for dealing with the problems.

In response to the report, Supervisor Judy Pennycook said, "We have folks out there that, basically, their lives are in peril. . . . I don't think we in the county of Monterey have done enough collectively for the people out there."

The study is funded by fees, approved in 1990 by the supervisors, that are charged to developers.

Total cost of the two-part study will be $538,000, said Mike Armstrong, water agency general manager. Collected fees were sufficient to pay for the first phase of the study, but not for the second phase.

As part of their action yesterday, the supervisors voted to extend the expiration date of the fees to Jan. 1, 1998, to pay for the rest of the study.

Martin Feeney, a consultant who has been working on the study for more than a year, told the board the North County area has about 3,000 wells and 400 small-water systems.

That part of the county is divided into four sub-areas, he said. The area closest to the Monterey Bay is heavily affected by seawater intrusion. On the eastern edge of the area, granite beneath the surface causes problems, and some wells fail.

But in the middle area, he said, wells are productive. Getting residents of that area to understand that their water comes from the same source as the water in the other parts of North County — and that it, too, is at risk — is difficult, Feeney said.

Overpumping is the problem, said Matt Zidar of the Water Resources agency, but blaming it all on residential development is wrong. Eighty-five percent of water use in the area is by agriculture, he said, while only 15 percent is by residential areas.

Even when the residential areas are built out, Zidar said, the proportion will stay about the same. Therefore, a building moratorium would not solve the problem.

See WATER PAGE 3C

The Monterey County Herald, January 17, 1996

North County water supply said declining

WATER FROM PAGE 1C

Feeney said 2,200 more residential units can be built in North County under current zoning, but agreed with Zidar that more land in the area would also enter agricultural use at that time.

The current overdraft is 100 percent more than the supply of water, he said. At total buildout, the overdraft will reach 200 percent of supply.

In contrast, overdraft in the Salinas Valley is just 8 percent, Feeney said.

Although several large water projects are in the works for the Salinas Valley, there are no such projects on the horizon for North County, he said.

Zidar said it was important for North County residents to know the whole area is "hydrologically connected."

That means, said Pennycook, "You can't rob Peter to pay Paul" — residents in areas where water seems to be abundant must know they are affecting the other North County areas, and that all face the same problem eventually.

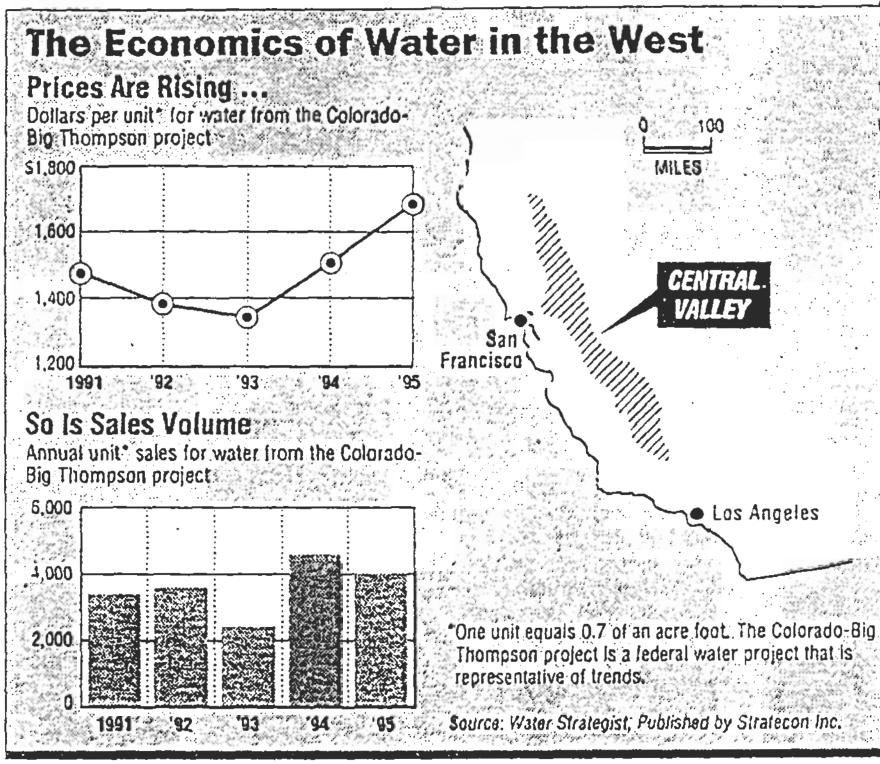
The study's second phase will include plans and procedures to protect groundwater quality and to protect against exceeding the safe yield of the underground aquifers.

It also will allocate available water supplies and establish the level of new development that can be supported in the absence of additional water supplies in North County, according to the ordinance approved by the supervisors in 1990.

Water Rights May Become More Liquid

California Agency to Float Electronic Trading Plan, Creating a True Market

By G. PASCAL ZACHARY
Staff Reporter of THE WALL STREET JOURNAL



SAN FRANCISCO — Just who gets water — and at what price — has long been an explosive question in the dry Western U.S., where water allocation is currently insulated from market forces by a crazy quilt of political and legal directives.

But this century-old tradition, designed to apportion the limited supply of water in the West, is giving way to economic incentive.

Next month, the nation's largest water agency will begin trading water rights electronically, creating what experts believe is the first true market for the buying and selling of that most essential of commodities.

Westlands Water District, in California's arid Central Valley, is launching the market, which at first will handle only water trades within the district. Westlands distributes cheap, federally subsidized water to about 700 farmers, including some of the nation's wealthiest and biggest agricultural operations, who grow cotton, tomatoes, garlic and other crops on an area the size of Rhode Island.

The Westlands electronic water market is being hailed as a potential role model by both agricultural interests and conservationists. "This is quite significant, path-breaking really," says Tom Graff, a senior attorney at the Environmental Defense Fund in New York City.

It also is a sign of the growing role that economic thinking plays in debates over natural resources. A growing number of "green" economists, for instance, complain that traditional economics doesn't account well for the value of natural resources and so understates the benefits of conservation.

At the same time, more environmentalists are beginning to accept the old economic saw that profit incentives can lead to environmentally sound outcomes. The keener appreciation for economics among conservationists is "part of a recognition that the important decisions are being made by people who listen to economists," said Jonathan Lasch, president of the

Please Turn to Page A6, Column 1

The Wall Street Journal, February 15, 1996

Water Enters the Electronic Age

Continued From Page A2

World Resources Institute.

That environmentalists are praising Westlands reflects this shift in orientation. For decades, Westlands has been attacked by Mr. Graff and many others as the epitome of the West's economically perverse and environmentally damaging system for federal water. In drought-prone California, for example, that system has left a relatively small number of farmers in control of about 80% of the water consumed in the state.

Water experts say Westlands' electronic market reflects a growing trend toward allowing market forces – rather than government directives – to apportion water in the West.

Many environmentalists like the idea because they think the most-valuable economic use of water eventually won't be pouring it on desert acres, but using it for drinking, producing high-tech goods and for some conservation projects, such as restoring salmon runs. Even in farming, a true market price for water will lead to more-productive farming.

"Water trading will play an increasing role in how water is used," says Craig Bell, executive director of the Western States Water Council, Salt Lake City. "As we move into an era without new supplies, trading will more and more play a role in moving water to the highest-value uses."

Current Informal Deals

In most Western states, water rights currently are sold through informal arrangements, mainly private deals made at coffee shops or over the telephone between farmers. Some states, such as Idaho, "bank" water for sale on behalf of farmers, but prices are fixed by the state. Even when prices are negotiated between buyer and seller, however, the pricing information often isn't widely available, or there isn't open bidding for the water.

"Right now you may be paying too much or too little for water, you don't know," says Erick Johnson, chief operating officer at Harris Farms, which receives Westlands water. "I'm looking forward to [the electronic market] because I hope it will give us more information and I'll make better decisions."

More-accurate information about the price of water trades is crucial to gaining the benefit of market forces. "It's not just what's sold – the more-important role is that everyone knows what the water is worth," explains Richard Howitt, an agricultural economist at the University of California at Davis. "Then a farmer can compare the cost of conservation methods with the real value of water he might use instead."

Mr. Howitt, who is helping to create the Westlands market, says that "eventually, we'll see multiple farmers bundle and package water rights," not just have one farmer sell rights to another.

Some Resistance Exists

These more-complicated trades could be years off. Although economic incentives should encourage more water transfers, observers say there is still resistance to them.

"One real inhibitor to marketing water has been people's fear that it could lead to their losing their rights to that water," says Lawrence MacDonnell, an attorney and water expert in Boulder, Colo.

That's possible, but not likely. A 1992 change in federal law eased restrictions on the sale of water rights. The law even sanctions profits earned by farmers on the sale of rights granted them by the federal government. That's a potentially volatile issue because agricultural users could reap windfall profits if they were to sell their water to cities, which would be willing to pay a huge premium.

"There are many taxpayers who are outraged at the idea of building a publicly funded project for farmers only to have them sell that same water to a third party and pocket the profit," says Hal Candee, a senior attorney at the Natural Resources Defense Council. But Mr. Candee says that some environmental groups, including his own, accept this. "Economists point out that you'll never free up water for transfer unless there's some profit to the seller," he says.

If farmers were to pay the true cost of their water, it is believed that there would be no objection to their making a profit on sales. "If people want to quibble with the [federal] subsidy, they should attack the subsidy directly," says Brian Gray, a professor at Hastings College of Law in San Francisco. Environmentalists have been doing that for decades, but agricultural interests have largely fended off such attacks.

Import Prices in December Rose 0.5%, Pushed by Fue

By a WALL STREET JOURNAL *Staff Reporte*

WASHINGTON – A spike in petroleun prices boosted prices of imports 0.5% ir December, the Labor Department said. Excluding fuels, however, prices were unchanged.

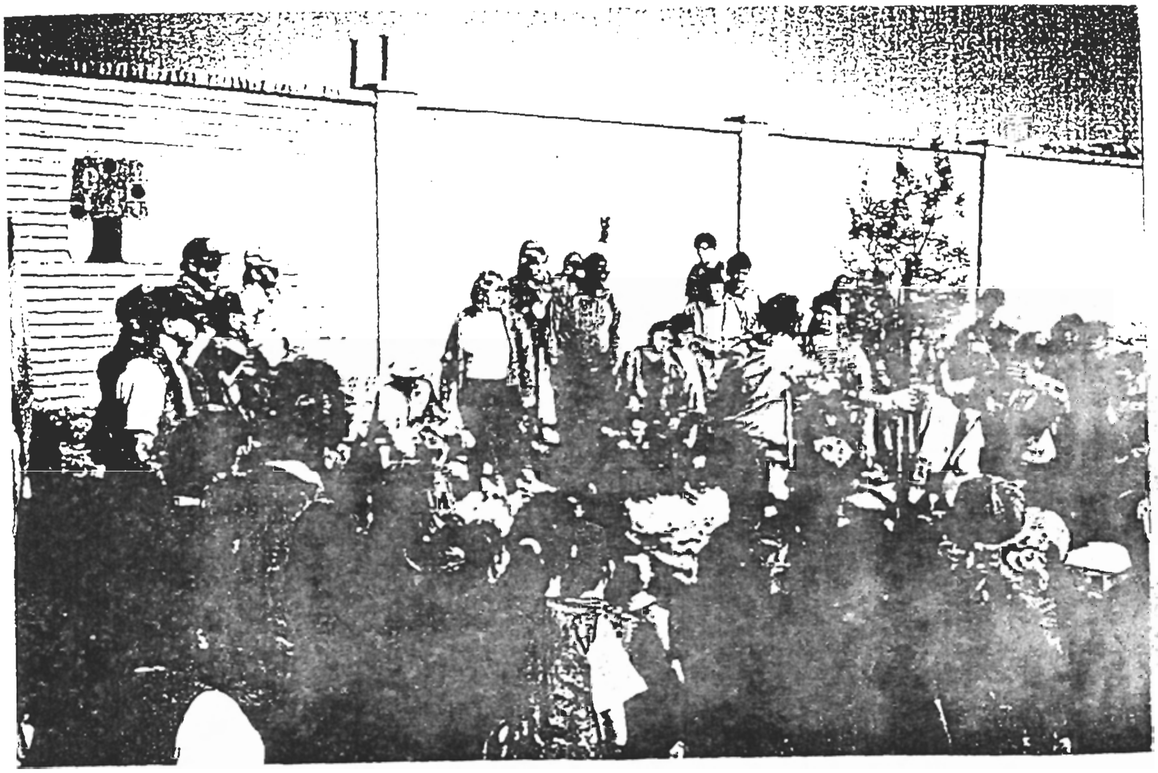
That compared with a 0.2% rise in the prices of all imports in November, while prices excluding fuels inched up 0.1%. The December index reflected a 4.3% jump in petroleum import prices following a mere 0.3% uptick the month before. Petroleum prices had been falling in the months before December, dropping 11.7% in the six months ended in November.

For all of 1995, import prices, excluding fuel imports, rose by 2.3%, compared with a 3.8% increase in 1994. Export prices were unchanged in December and rose by 3.3% for 1995, the government said.

The Wall Street Journal, February 15, 1996

Appendix III
Return of the Natives Planting Day

Return of the Natives planting day at a Salinas grammar school, where college and high school interns and other mentors help younger students, teachers, and community volunteers.



Return of the Natives planting day on a hillside above the Natividad Creek. Area schools are supplied with greenhouses where many of the plants are grown in watershed science projects.

Appendix IV

Salinas Park Work Coming in Under Cost:

Congress could Learn from Natividad Creek Park Effort

Salinas park work coming in under cost

BY JOE LIVERNOIS

Herald Staff Writer

A plot of land that will become the largest municipal park in Salinas is taking shape, with playground equipment installed and thousands of new plants in place.

The first phase of the Natividad Creek Park could open next summer, unless the rains just don't stop, according to Ed Piper, facility planner for the Salinas Recreation-Park Department.

And today the City Council will be told that the group hired to plant the trees underspent its budget by more than $50,000.

The group, Return of the Natives, will ask the city if it can use the money to develop plans for an "interpretive" facet to the nature park. City officials initially planned to include signs to describe the plant community and include a "children's discovery garden," but didn't think they had the money, Piper said.

"With limited funding, it is rewarding to be able to complete a project at a cost lower than anticipated and to be able to utilize surplus funding to expand the project," Piper said.

New Salinas park is shaping up

PARK FROM PAGE 1C

Return of the Natives used school groups and volunteers to plant more than 18,000 trees and bushes on 14 acres of the 64-acre park. All the plants are native to the Central Coast area.

Piper said the group recruited so many volunteers, contributions from scientists and restoration specialists that it saved thousands of dollars. In addition, most of the plants were grown in greenhouses tended by students at several schools in Salinas.

The natural area of the park will include trails.

"It's kind of great," he said, "since the schools that helped create the park will benefit from it."

The Return of the Natives operated with a $160,000 state grant and $85,000 in city park fees.

Piper said that when it opens later this year the rest of the park will include tennis courts, basketball courts, a multi-use playing field, picnic grounds, an amphitheater and a gazebo.

Meanwhile, the city has plans to include a BMX bicycle track and a skateboard course at the park. The city now has money to plan for the recreational sites, but must decide how to fund construction, Piper said.

Natividad Creek Park is located off Boronda Road in the Creekbridge subdivision in Central Salinas.

Monterey County Herald, March 15, 1996

EDITORIAL

Congress could learn from Natividad Creek Park effort

WHERE WE STAND:

Salinas finds a resource in its volunteers and conscientious leaders to save money and create opportunity.

Give the people what they want.

If we're talking about taxpayers, they want the money they give to government to be used efficiently and with expedience.

That's what appears to be happening with money being used to construct Natividad Creek Park in northwest Salinas. The 64-acre park, the first phase of which is expected to open this year, will be the city's biggest and maybe its best. Once finished, Natividad Creek Park will include the usual fare of playgrounds, ball fields and courts, picnic areas and tennis courts. It also will feature a moto-cross bicycle course and skateboard course, an amphitheater and a nature area.

The nature area is today's focal point. Park plans to restore natural vegetation and habitats to one park area has attracted an army of community volunteers. These volunteers, about 4,000 in all, helped grow plants and make preparations for restoring the nature area.

This effort has trimmed $50,000 from a $160,000 state grant! An insightful contractor and frugal non-profit group also did their part to save the money.

The City Council should approve spending the $50,000 savings on more features for the park.

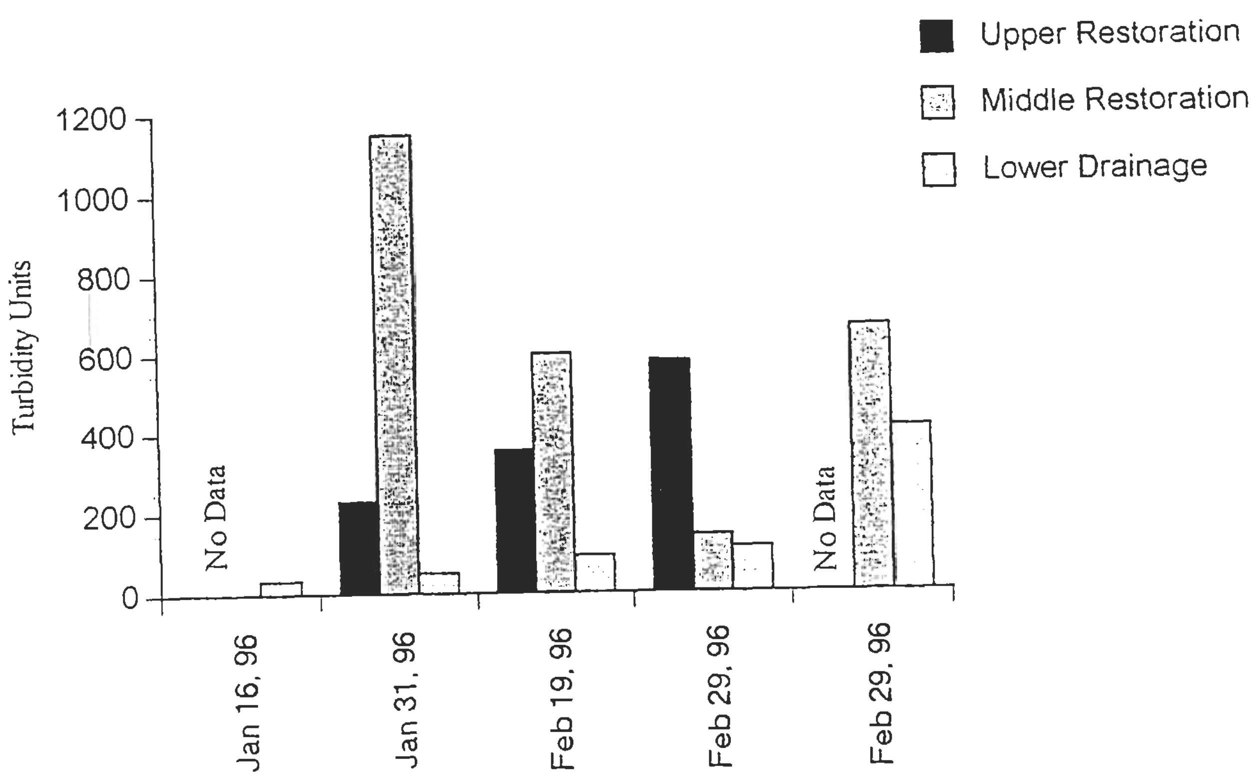
What's the key to cutting government spending? At the local level, it starts with getting the community to buy into the project. In Salinas, citizens want more parks, more open space. And they apparently are willing to devote more than tax money to get it.

Congress can learn something from the good people of Salinas and their friends who are pitching in to make their city a better place to live.

The Californian, March 1996

Appendix V
Moon Glow Dairy Turbidity Measurements

Moon Glow Dairy Turbidity Measurements



Appendix 7

Return of the Natives

1996 Progress Update

Progress Update

Propagation and Restoration:

• To date, over 1,354 students were involved in propagation of native plants in six RON school greenhouses. Over 20,000 plants were grown to outplanting size. 53 teachers and at least 24 parents were involved.

• This past rainy season, six school planting days and two community planting days were held in various locations throughout the park. Approximately 1730 students and 240 community volunteers participated, and planted approximately 20,000 native plants.

• Refurbishment and seeding of all six greenhouses was accomplished in September 1996. Events were well attended by parents and students, and coordinated by RON staff. Typically excellent coverage was given by newspapers and TV stations.

• In an evaluation conducted by RON Teacher and School Liaison, Peter Moras, teachers scored the enjoyability of the greenhouses 9 and the educational benefit 8 on a scale of 1 - 10.

• Approximately 1,000 plants have been grown and are being maintained at the Watershed Institute for use in the Children's Discovery Garden.

• School greenhouses are currently growing plants for other Salinas restorations such as Cesar Chavez Park, as well.

Enrichments and Training

• A propagation workshop for teachers was held on February 21, 1996.

• RON enrichment on use of internet to augment restoration curricula held at Alisal High School on May 9.

• About 80 high school students and teachers attended an April 13 Restoration Ecology Symposium at the Watershed Institute.

• Scheduled RON workshop for October 25 and 26 to train more RON teachers.

• RON sponsored CSUMB service learning students to serve as RON mentors in Salinas schools and leaders at planting events.

Recognition

• RON teacher and steering committee member Lynn Hamilton was honored by the Community Achievement Recognition Council (CARE) for her work with RON projects.

• RON to Natividad Creek Park continues to get excellent media coverage (TV and Newspaper at park planting and greenhouse events.

• RON curriculum library moved to Watershed Institute at CSUMB; a $1,00 grant was received from the Campus Compact Organization to augment the library.

• RON video produced by CSUMB Service Learning student.

• RONwas cited by Private Industry Council for restoration project involving at-risk students.

• RON booths at Earth Day in Toro Park (April 20) and at Barnyard event titled "A Garden Affair"

Interpretation

• Staff from RON and Joni Janecki & Associates conducted a number of meetings and site visits to plan interpretive elements.

• Several planning meetings held with Ed Piper of City Parks for input and updates.

• Two school and community meetings held to get public input to the interpretive plan.

• A draft interpretive master plan was prepared, submitted and reviewed; and a final plan has been submitted. This plan includes site drawings, numerous schematic and concept drawings, as well as a detailed drawing of the Children's Discovery Garden.

• Initial site work for the Children's Discovery Garden accomplished in at least 15 work days involving up to 12 laborers and volunteers each day. Work included delineation of the trails; digging trails and interactive stations; installing stumps, trunks and boulders; and overseeing large equipment activities by City workers. City staff and volunteers alike were outstanding in their energetic contributions to the project. Participants included the California Conservation Corps, Americorps, Boy Scouts, CSUMB Service Learners, and Salinas Community School. Hours were spent on the phone with City staff coordinating construction of the Discovery Garden. Over $1,000 worth of materials and transport (e.g. sand) were donated by a number of area businesses and agencies.

• RON staff attended several meetings of the Salinas Peace Builders to investigate the possibility of linking the Children's Discovery Garden with their important objectives. Response was favorable, and Peace Builder elements are being woven into the interpretive elements of the garden.

• RON staff researched and selected materials and vendors for interpretive signage. A minimum of six 24" x 36" interpretive signs will be installed this year. RON staff are working with local artists and designers to design and illustrate graphic panels.

• A November 23, 1996 Interpretive Planting and Work Day is planned for the Children's Discovery Garden. CSUMB proseminar and service learning students assist as mentors during the event. At least one additional planting event will be scheduled for this rainy season.