WATER RESOURCES MANAGEMENT PLAN FOR WATSONVILLE SLOUGH SYSTEM SANTA CRUZ COUNTY

ambag

local control through regional cooperation

ASSOCIATION OF MONTEREY BAY AREA GOVERNMENTS

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Prepared For

Association of Monterey
Bay Area Governments
(AMBAG)

Prepared By

Questa Engineering Corporation
Point Richmond, California

November 6, 1995

APPENDICES

WATER RESOURCES MANAGEMENT PLAN

FOR

WATSONVILLE SLOUGHS

SANTA CRUZ COUNTY

Prepared For

Association of Monterey
Bay Area Governments
(AMBAG)

Project #94028

Prepared By

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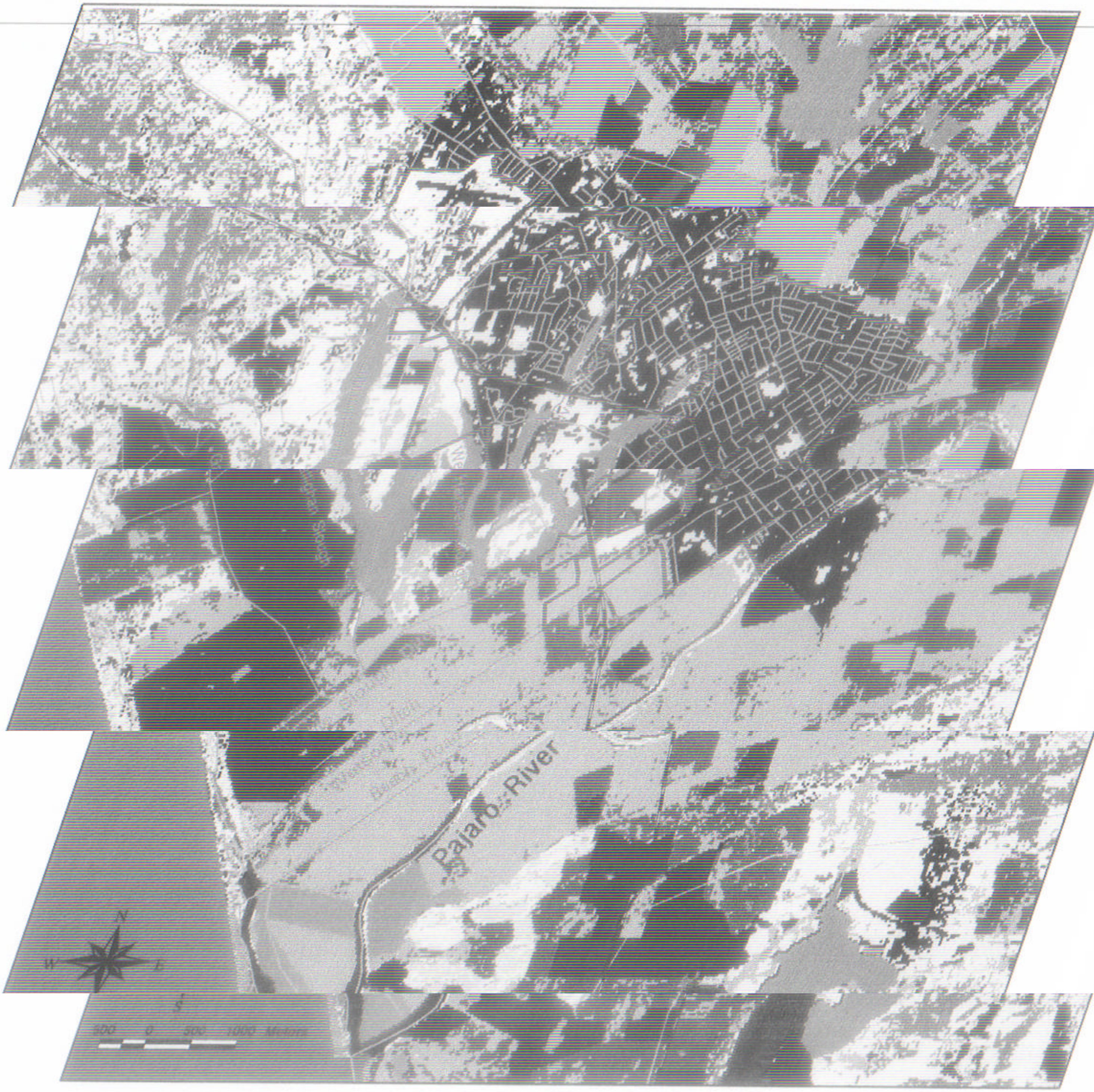

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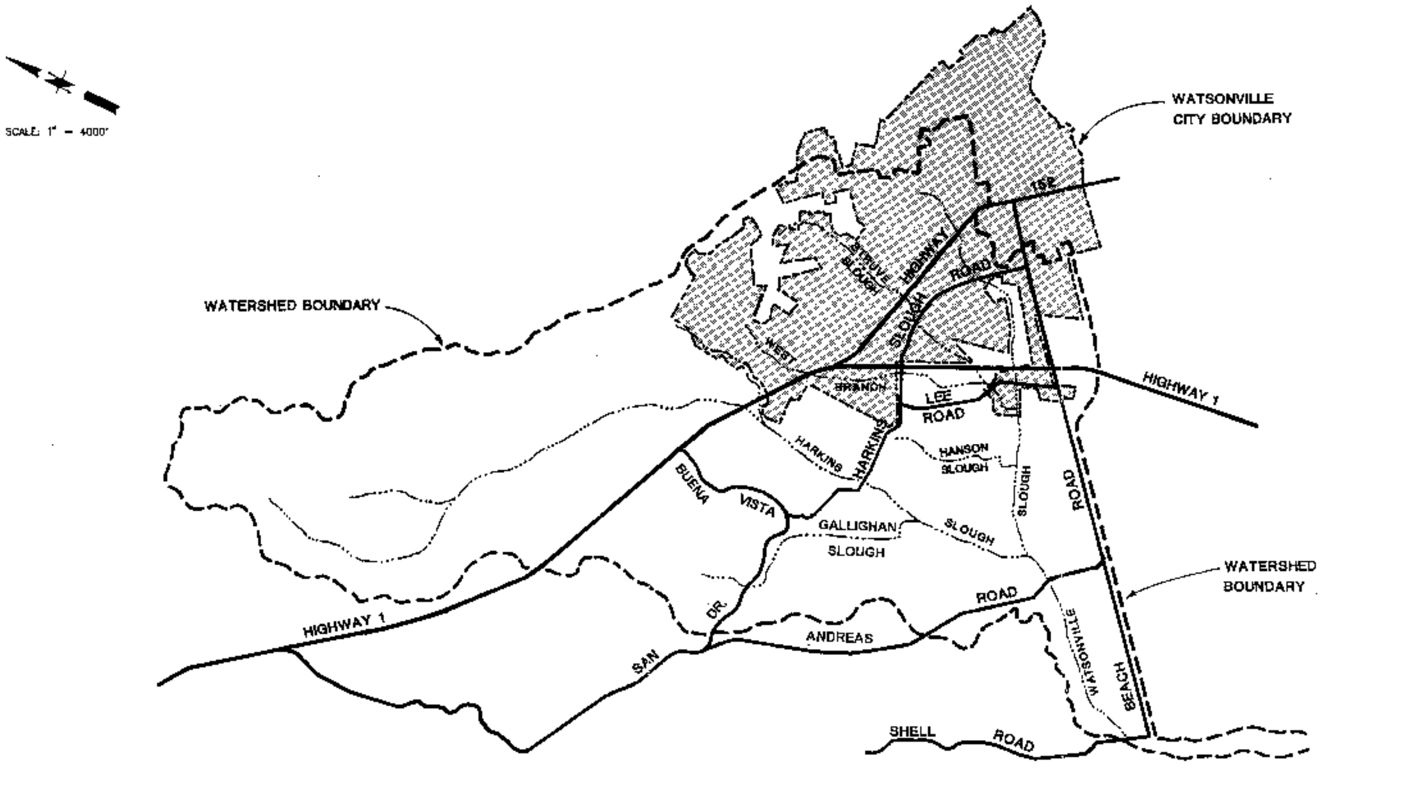

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POINT RICHMOND, CALIFORNIA

WATSONVILLE SLOUGH SYSTEM
WATERSHED AREA

FIGURE
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SECTION 1

EXECUTIVE SUMMARY

BACKGROUND

The Watsonville Slough System in Santa Cruz County is an extensive wetland complex which is a regionally significant habitat area for waterfowl, rodents, amphibians and seed-eating birds. The slough system has been altered and impacted by encroachment and by other land use and watershed activities. It has been designated by the State Water Resources Control Board as having impaired water quality.

In response to the evidence of water quality and other environmental degradation, the Watsonville Slough System Water Resources Management Plan (Management Plan) was undertaken by the Association of Monterey Bay Area Governments (AMBAG), with funding from the SWRCB and the support of the County of Santa Cruz, the City of Watsonville and other resource agencies and interest groups in the area. The purpose of the Management Plan was to: a) investigate and develop baseline information on the hydrologic and water quality conditions in the slough system; b) identify primary sources of non-point pollution entering the wetland areas; and, c) evaluate and recommend alternative watershed management practices and other pollution control strategies to improve water quality while also enhancing the wetlands and water management in the system.

The Watsonville Slough System watershed contains a diverse mix of land uses, including extensive agriculture and urban development; and it is expected that this mix of land uses will continue to exist for the foreseeable future. It was not the intent of this study to compare the watershed effects of urban and agricultural land uses against one another as a basis for shaping future development in the area; each has their own effects and needs for pollutant control and water resources management. Any attempt to use the results, conclusions or recommendations of this study to argue for or against any particular type of future land use conversions is inappropriate.

WETLAND RESOURCES

The Watsonville Slough System is an interconnected series of primarily freshwater, palustrine wetlands, separated from a smaller coastal salt marsh which joins the Pajaro River near its mouth. The Watsonville Slough System is generally recognized as the largest and most significant wetland habitat between Pescadero Marsh in San Mateo County to the north and the Elkhorn Slough in Monterey County to the south. The slough system contains remnant but, nonetheless, significant areas of salt-marsh and brackish marsh, riparian and oak woodlands, dune and coastal scrub communities, bodies of open water and perennial freshwater marsh and seasonal wetlands. The great diversity of habitats present within the relatively small watershed and its occurrence on the Pacific Coast flyway make the slough system especially important as a refuge, feeding and resting area for migratory, winter and resident waterfowl.

HYDROLOGY

The Watsonville Slough System is composed of a branching network of six seasonally wet sloughs/wetlands. Watsonville Slough is the main branch, with five other tributary arms (Harkins, Galligham, Hanson, West Branch of Struve and Struve Slough) that extend up the eroded valleys of former marine terraces. About half of the urbanized areas of Watsonville and the town of Freedom occupy land area in the watersheds of Watsonville, Struve and West Branch Sloughs. The remainder of the watershed is dominated by primarily irrigated farmland, rural residential development and intervening open space.

The sloughs themselves are generally shallow, open channels with accompanying broad flat floodplain/wetland areas that hold, transport and drain the precipitation and irrigation runoff for all or parts of the Watsonville, Freedom and Larkin Valley areas, as well as the Pajaro Valley farmlands along Beach Road. The channels are usually less than 35 feet wide with low (two to four-foot) banks. During the winter these channels rapidly exceed their capacity and spill over into broader flood plains/wetland areas. Due to the low gradient and runoff velocity, the channels readily accumulate sediments eroded from the watershed. This requires the channels to be maintained by the landowners and by the Santa Cruz County Public Works Department (through the Pajaro Storm Drainage Maintenance District), involving periodic dredging of accumulated sediment and clearing of vegetation and debris. However, to date this activity has not been carried out on a regular basis.

There are two pump stations within the sloughs system: (1) on Harkins Slough at its confluence with Watsonville Slough; and, (2) the main Shell Road pump station, which discharges winter and summer flows into the tidal reach. These pump stations are operated by float controls to provide winter flood protection and positive drainage for local agricultural lands during the summer.

Soil erosion in the watershed is significant from the standpoint of sediment deposition in the sloughs and floodplain/wetland areas, but also due to the transport of nutrients and other pollutants that may be attached to the soil. During runoff events soils in the slough watersheds are constantly subject to erosional forces. The Watsonville Slough System has a wide variety of soil conditions and land uses which are affected by differential amounts of erosion. Human activities such as agriculture and construction can greatly increase erosion rates. A portion of the hydrologic study involved a review of existing soil conditions and the application of the Universal Soil Loss Equation (USLE) to develop rough estimates of erosion potential from different areas of the watershed. The analysis showed the greatest potential for erosion to be in the hilly agricultural watersheds tributary to Galligham and Harkins Slough. The field observation of rills and gullies in the hillsides suggests an excessive erosion rate that likely exceeds 15 tons/acre per year in localized areas.

To help understand the occurrence and movement of water through the sloughs, a detailed water budget was developed. The water budget is essentially an input-output model that accounts for all of the inflow to and outflow from the slough system. It takes into account the rainfall-runoff relationships, groundwater recharge to both the shallow alluvium and deep Aromas aquifer which underlies the Watsonville and Pajaro River area, agricultural irrigation, and evapotranspiration losses. The water budget was completed and tested for "average", "wet" and "dry" year rainfall conditions. In average years, winter runoff peaks at about 1,600 to 1,800 acre-feet per month, and declines to a minimum summer flow of 100 to 150 acre-feet per month, largely due to shallow groundwater discharge and irrigation return flow.

WATER QUALITY

Historic Water Quality Findings

Degraded water quality conditions in the Watsonville Slough System have been documented by several studies over the past 15 to 20 years, including on-going monitoring by the County of Santa Cruz and periodic sampling by the Central Coast Regional Water Board. Identified problems include those associated with pesticide accumulation in sediments and aquatic organisms, high nutrient levels, localized algal blooms and, periodically, low dissolved oxygen and toxic levels of ammonia.

The most significant water quality concern in the Watsonville Slough System has been the accumulation of pesticides and PCBs, which have appeared at elevated concentrations in tissue sampling of fish and invertebrates (SWRCB, June 1991). This tissue sampling occurred between 1984 and 1993 as part of the State Mussel Watch (SMW) and Toxic Substances Monitoring (TSM) programs. During this period, twenty-one tissue samples from the Watsonville Slough System were analyzed for numerous toxic substances. Eleven of the twenty-one samples exhibited levels of one or more pesticides and/or PCBs that exceeded the National Academy of Sciences (NAS) recommended guidelines for aquatic organisms. The pesticides for which NAS guidelines were exceeded included DDT, Chlordane, Dieldrin, Endosulphan, Toxaphene, and Hexachlorobenzene (see **Section 6** and **Appendix D** for a summary of the SMW and TSM results). Some of the highest levels of pesticide contamination found in California by the TSM and SMW programs occurred in the Watsonville Slough System.

Current Water Quality Monitoring

Under the present project water quality monitoring was conducted following compilation and review of historic water quality data. The sampling stations were selected to verify previous data trends and to fill "data gaps" with respect to geographic needs and uncertain water chemistry. In general, the objective was to gather information for all sub-watersheds. Ten sampling stations throughout the Slough System were selected for inclusion in the monitoring program.

Sampling was conducted at the end of the dry season and during, or soon after, major storm events during the fall and early winter of 1994. Water quality sampling was completed for one non-storm period (September 1994) and for three runoff events, one each in October, November and December. Analyses were completed for a number of standard physical parameters (e.g., pH, conductivity, suspended solids, etc.), ammonia, nitrate, phosphorous, several metals and various pesticide scans.

Summary of Water Quality Problems

Based on historic data and findings from the current investigation, following is a summary of the water quality problems in the Watsonville Slough System.

- **Sedimentation**. Sedimentation in the sloughs due to soil erosion is a major water quality problem. The sediments deposited in the slough channels obstruct and alter drainage patterns, reduce water clarity, blanket vegetation and aquatic organisms, and transport attached nutrients and pesticides into the receiving waters. Agricultural lands are the primary source of soil erosion; but erosion also occurs in connection with urban and rural development, as well as naturally, due to the high erodibility of the sandy soils in the watershed.

- **Nutrients**. Two nutrients, nitrate and phosphate, are found in Watsonville Slough System at high concentrations. These nutrients can contribute to increased algal growth with consequent impairment of water quality for other organisms and from an aesthetic standpoint. However, no definitive impact on beneficial uses can be determined from these nutrient levels, since the water in the sloughs does not presently serve as a source of drinking water, and extensive widespread algal growth and depressed DO levels have not been observed.

- **Ammonia**. Ammonia levels in most of the sloughs generally exceed recommended limits for sensitive aquatic species; but the levels are not unusually high for wetland water bodies where there may be large waste contributions from wildlife and waterfowl populations. Additional sources may also include leaching from livestock areas or manure stockpiles and, to a limited degree, from sewer or septic system bypasses/leaks and possibly releases of ammonia products in commercial, industrial or residential areas.

- **Pesticides**. Pesticides, including current as well as historically but no longer used compounds (i.e., DDT), have been occasionally detected in water quality sampling of the sloughs, particularly during runoff periods. When detected, many of the readings have been in excess of water quality criteria for these pesticide compounds; many pesticides do not have established standards. The most significant evidence of water quality impairment in the slough system is the accumulation of extremely high levels of pesticides in fish and shellfish tissue samples. Agricultural pesticide use is the main source. Runoff from urban sources may also contribute small quantities of pesticides to the sloughs from landscaping uses; but sampling, to date, has not shown this to be a source. Pesticides attached to soil particles are transported to the sloughs through erosion. The transported pesticides may be those in current use or former pesticides that still remain attached to soil particles.

- **Fecal Coliform**. Sampling in the Watsonville Slough System for coliform has been conducted by Santa Cruz County from time to time. Results of routine sampling of several different stations for the period of July 1994 - July 1995 are provided in **Appendix D**. Included are stations on Watsonville Slough, Struve Slough and Harkins Slough. Spot measurements taken in 1987 - 1992 are also listed. The data show a range of results, typically from <100 MPN/100 ml to about 1,000 MPN/100 ml. There are also a few isolated readings in the range of 2,000 to >11,000 MPN/100 ml. About half of the results exceed 400 MPN/100 ml, which is the maximum limit for water contact recreation waters. As another point of reference, samples taken by the PVWMA in April 1995 showed readings of 43 and 240 MPN/100 ml, respectively, at Harkins Slough (Pump Station) and Watsonville Slough (upstream of Harkins Slough). Generally the coliform data show significant levels of bacteria in the sloughs that are likely the result of animals and waterfowl; but there could also be input from septic systems or sewage overflows from the urban area. No surveys or site specific sampling has been done to determine the sources of high coliform readings in the sloughs.

- **Heavy Metals**. Copper, nickel, lead and zinc are the principal metals found consistently throughout the sloughs at levels in excess of criteria for freshwater aquatic species. These constituents are characteristically the primary heavy metals found in urban runoff; but sampling in the sloughs show them to occur in both urban and agricultural drainage areas. Copper compounds used in connection with farming activities or at specific industrial sites are possible contributors. The County and City landfills are potential sources of heavy metals (via leachate); but, there is no evidence that they are a current source of heavy metals to the sloughs and both landfills have leachate control programs as well as on-going monitoring requirements.

- **Oil and Grease**. Detectable concentrations of oil and grease are found in the areas of the sloughs near Highway 1 and the City of Watsonville. At the levels reported a sheen may be visible under certain conditions. However, no exceedances of water quality standards (visible oil sheen) were noted during this study. Motor oil leaks, exhaust and spills are the principal sources of oil and grease at these locations. Elsewhere in the sloughs oil and grease is nondectectable due to limited sources and the probable effectiveness of wetland vegetation as a filtering mechanism.

- **Litter and Debris**. Urban litter and debris accumulate in various locations of the sloughs due to runoff from city streets, as well as direct, illicit littering and dumping in roadside ditches and the sloughs themselves. The accumulated debris is unsightly, can contribute to the obstruction of culverts, and possibly introduce hazardous chemicals or other deleterious substances to the water.

- **Water Flow and Circulation**. The sloughs contain extensive areas of stagnant and slow moving water due to the flat gradient and additional obstructions to flow caused by road crossing, blocked culverts and sediment build-up. The urban development in the watershed, with associated streets, storm drains and other impervious surfaces has altered the hydrology by increasing winter runoff peaks and reducing groundwater recharge and spring/summer base flow contribution. However, this is off-set to a degree by the percolation and return flow from irrigation of agricultural lands.

MANAGEMENT OPTIONS

Based on the identified water quality problems and watershed conditions and activities, a broad range of potential Best Management Practices (BMPs) were identified. BMPs are defined as any program, technology, process, siting criteria, operating method, or device which controls, prevents, removes or reduces pollution (SWRCB, 1993). For the purposes of this project, BMPs were separated into two categories: (1) source control measures; and, (2) downstream treatment measures. Source control refers to specific measures that can be taken at specific locations and in the watershed area to remove or minimize pollutants at their source. Downstream treatment refers to physical measures to improve water quality or removal of pollutants within the slough system.

Source Control Measures

Source control measures (BMPs) were identified for urban, agricultural and rural residential land uses. Examples of urban area BMPs related to such things as construction site erosion control storm drainage design, vegetated buffer strips, oil/grease separators, public education and storm drain signage to minimize pollutant discharges to water bodies. Agricultural area BMPs covered such practices as erosion control practices and ordinances, irrigation water control, vegetated buffer strips, fertilizer and pesticide management and animal waste control. Rural residential area source control measures relate principally to septic system practices and livestock waste management.

Downstream Treatment Measures

Following are a listing of the various downstream treatment alternatives considered for the Watsonville Slough System.

- **Wet Detention/Sedimentation Ponds**. The installation of wet detention/sedimentation ponds (i.e., permanent ponds) can be a very effective multi-purpose water quality treatment measure. The proper construction and maintenance of the pond will result in high removal rates of sediment, organic matter nutrients, and trace metals.

- **Drainage Modifications**. This measure would entail modifying existing drainage structures to improve water flow, circulation and increase inundation area in the sloughs. The need for such drainage modifications is throughout the sloughs.

- **Channel Dredging**. In order to maintain flood control and channel conveyance the lower sections of Harkins Slough and the freshwater section of Watsonville Slough are dredged of sediment that accumulates from erosion in the watershed and adjacent agricultural lands. Water quality conditions are improved by the physical removal of sediment (and attached pollutants) from the sloughs; however, the dredging practices themselves (backhoe and clamshell operations) also suspend large quantities of sediments, nutrients, pesticides and metals in the water column, resulting in a temporary, but potentially significant, localized water quality problem.

- **Channel Filling**. This management measure would involve filling portions of existing drainage channels within the sloughs to create a more dispersed flow and shallow spreading of water; the aim would be to increase runoff contact with soil and vegetation to improve water quality and to expand wetland vegetation areas.

- **Constructed Wetlands**. Constructed wetlands can enhance stormwater and irrigation runoff water quality by removing oil and grease and causing the settlement of pollutant-laden sediments. They work much the same way as wet detention structures previously described.

- **Flow Diversion**. This management measure would involve intercepting runoff and drainage (e.g., tile drains and industrial site runoff) from pollutant generating sources and diverting it elsewhere for discharge.

- **Slough/Tailwater Recirculation**. A potential management measure in the lower freshwater portion of Watsonville Slough (above Shell Road) would involve the recirculation of agricultural return and natural flow of water in the sloughs during the summer and dry fall months.

- **Vegetative Riparian Buffers/Filterstrips**. Vegetated/riparian buffer strips are most commonly used for pollutant removal along highways and adjoining residential areas; but they also have definite applicability as treatment BMPs in the Watsonville Slough System watershed, especially where the historic sloughs have been converted to narrow earthen ditches bordered closely by agricultural fields.

- **Flow Augmentation**. This measure would provide for the introduction of additional dilution flows to the sloughs during the dry season. The flow within the slough could potentially be augmented with a portion of the water diverted for the PVWMA recharge project or with reclaimed wastewater from City of Watsonville treatment plant, if either of these projects is implemented.

- **Water Level Controls**. This management measure would entail adjusting water levels in the slough and/or detention structures to achieve greater pollutant removal. This could be accomplished at road crossings within the slough system or at constructed wet detention basins within the watershed.

RECOMMENDED MANAGEMENT PRACTICES AND FUTURE STUDIES

The alternative management measures for water quality improvements presented are based primarily on the professional judgement of the consultant. They were compared in a preliminary manner with regard to several factors, including: (a) effectiveness in addressing identified water quality/degraded wetland problems; (b) engineering technical feasibility; (c) impacts to other competing water/land management interests in the watershed; and, (d) likely ability to be implemented. From this review, an array of conceptual management measure recommendations were developed, along with estimated costs, illustrative diagrams, and identified steps required for implementation. Also identified are additional studies where they appear to be warranted.

This list of alternatives and resulting recommendations was not based upon a conventional cost-effectiveness analysis, since a specific treatment objective was not defined as a common basis for comparison of alternatives. Rather, the analysis, in accordance with the defined scope and approach for the project, relied heavily on professional judgement of the consultant team to estimate the best means of improving water quality while at the same time balancing the competing interests of many different stakeholders.

Recommended Source Control BMPs

Nearly all of the source control BMPs identified were determined to have applicability and would benefit the water quality improvement efforts in the Watsonville Sloughs. Clearly, some measures would be more effective than others; some are more easily implemented than others; and, many of the identified BMPs are already in place.

Recommended Downstream Treatment Measures Summary

Downstream treatment measures in the sloughs have the potential to effect the greatest degree of improvement in water quality and wetland conditions. From the range of alternatives evaluated the measures recommended for implementation were as follows:

1. Constructed wetlands/wet detention or treatment of low-flow urban and highway runoff; located on the reach of Watsonville Slough both upstream and downstream of Lee Road and at the end of the Beach Road Ditch. However, the effects of pollutant concentration in wet pond/detention areas are not known or predictable. Evaluation of these effects should be completed prior to the implementation of these recommendations.

2. Slough and irrigation tailwater recirculation for high rate irrigation of a created vegetated/riparian buffer along the Watsonville Slough downstream of San Andreas Road.

3. Vegetated channel terrace and riparian buffers along reaches of Watsonville and Harkins Slough above San Andreas Road.

Recommended Actions and Future Studies

Water quality impairment in the Watsonville Slough System has been known to exist for the past 10 to 15 years, based largely on the State Mussel Watch and Toxic Substances Monitoring Program findings. However, the full extent of water problems and their relationship to land use and water management activities in the area had not been studied prior to this project. The review of historic data, combined with additional water quality monitoring in the present study has improved the understanding of the slough system water quality; but it has not produced definitive information on the source(s) of specific water quality conditions (e.g., chronic high ammonia levels in Struve Slough), nor answers to the question of the actual beneficial use impacts of certain constituents that are above standard criteria (e.g., nitrates and several heavy metals). The downstream treatment recommendations outlined above are, in the judgement of the consultant, the best types of measures that can be employed to improve the water quality conditions, while also achieving stated wetland restoration aims and minimizing adverse impacts to other water management interests in the watershed. But these measures can only be viewed as conceptual plans and tentative conclusions, given the lack of information or answers to several key issues, particularly in regard to the specific sources of pollutants and the degree of impact on beneficial uses. Based on the significant costs and other impacts involved with the implementation of these or other downstream treatment measures identified in the study, it is only prudent that further study be completed in several areas (see below), before a firm decision is reached on implementation of the costly downstream treatment measures recommended by this plan. Also, other less extensive and less costly measures (e.g., source control BMPs, water quality monitoring) can be taken immediately to address some of the site specific problems in the watershed; this may aid in understanding the overall water quality conditions, as well as possibly correcting some specific problems. The recommended actions and additional studies needs are briefly outlined below.

1. **Site Specific Monitoring and Abatement Efforts.** Efforts should be continued to apply BMP measures to adjacent and nearby land uses according to the recommendations in **Sections 7** and **8.1** of this report. As the Monterey Bay Sanctuary's Water Quality Protection Program's components are developed and adopted by the City of Watsonville and Santa Cruz County, and as further studies and monitoring of pollutant sources are undertaken, the information and recommendations of this Plan should be incorporated and adapted into the City's and County's programs. The objective should be to refine and apply those BMP measures that are most effective in eliminating those pollutants identified in the Watsonville Slough System to those areas of the watershed most likely to generate such pollutants.

   In order to accomplish this and to identify and abate actual or threatened pollutants discharges adversely affecting the water quality conditions in the sloughs, intensive water quality monitoring and surveillance of various land use activities and operations in the watershed should be undertaken by local officials, citizen volunteers, and/or landowners and business operators. This should be done systematically to cover the potential sources cited in **Section 6.1** of this report, as well as any other sources that may be identified. A joint task force involving the City, County, Coastal Commission, AMBAG and others could be formed and utilized to coordinate and monitor this effort. Where actual, uncontrolled pollution is discovered, it should be reported to the Regional Water Quality Control Board and the Department of Fish and Game, who would initiate enforcement actions where necessary (i.e., cleanup and abatement orders, citations or fines).

2. **Watsonville Slough System Master Plan.** Development of a more comprehensive Watsonville Slough System Master Plan should be considered to address resource issues that were not in the scope of this study. Such a master plan could include the determination and mapping of historic wetland extent, wildlife corridors, appropriate wetland buffers, and areas suitable for wetland or upland habitat restoration. Also to be assessed would be areas for potential public acquisition and/or access.

   A wetland restoration model should be an element of any slough master plan, and should include information on historic conditions, current constraints (e.g. landowner cooperation), and proven wetland restoration methodologies. An overall master plan would more comprehensively examine the biological, hydrological, and land use attributes of the slough system watershed than does this report, and should derive objectives and recommendations regarding all wetland functions -- water purification, flood water storage, animal and plant habitats and migration corridors, recreation and aesthetics, etc.

The master plan should recommend wetland buffer standards and strategies for maintenance/management and interagency cooperation. While these objectives were not in the scope of this water resources management plan, this plan would serve as the basis for the overall slough system master plan.

AMBAG should reapply for a Clean Water Act Section 205(j) grant to complete this next phase. If a grant is not forthcoming, other funding sources should be pursued. In the interim, individualized restoration efforts, such as those described in this report on Hansons Slough and Harkins Slough (pp. 5-17 - 5-18) should continue and be encouraged.

3. **Water Quality Studies**. The following additional water quality studies are recommended to guide the selection of appropriate management practices for water quality improvement:

   - **Ammonia**. Study ammonia toxicity thresholds for slough system aquatic species and investigate the sources of chronic elevated ammonia levels in Struve Slough.

   - **Metals**. Investigate metals accumulation in slough sediments and aquatic organisms to determine the degree of toxicity and appropriate local objectives for copper, lead, nickel, and zinc. This should be coordinated with the soon-to-be-released toxicity studies being conducted by UCSC.

   - **Nitrate Sources and Biostimulation**. Study the relationship between elevated nitrate and phosphate levels (or other biostimulatory factors) and algae production in the slough system; combine this with comprehensive survey of dissolved oxygen and algae blooms in shallow stagnant water zones. Additionally, more intensive sampling should be conducted to pinpoint the sources of the periodic high nitrate concentrations, and to pursue control of these sources as appropriate.

   - **Pesticides**. Continue SMW and TSMP tissue analysis and correlate findings with sediment concentration data.

   - **Coliform**. Coliform data should continue to be collected by the County and follow-up site investigations should be made to identify and address the sources where repeated high readings (e.g., 1,000 MPN/100 ml or greater) are observed.

4. **Recommended Drainage Operation and Maintenance Practices**. Better records should be maintained of water levels in the slough system, operation of the pump system, dredging and other operations. Staff gages and/or water level recorders and pump meters should be installed and read regularly. Improved management of pumping regimes and water level controls could be implemented in addition to, or instead of, flow augmentation. The possibility of installing gated culverts at road crossing (e.g. Lee Road, Harkins Slough Rd., Walker St.) should be explored as a means of allowing for greater human control over water levels in different portions of the slough system (e.g. intentional impoundment of water to increase the hydroperiod for certain wetland areas, etc).

5. **Flow Augmentation.** Studies should be continued regarding the potential for flow augmentation in the slough system during the low flow periods. This should consider reclaimed wastewater from the City of Watsonville as one source and also potential augmentation in connection with the PVWMA diversion/aquifer recharge project. The studies should evaluate such factors as volumes and timing of water, the associated water quality, potential release points in the slough system and downstream water quality effects(e.g. depressed salinity) in the estuary. There may be competing uses for this supplemental or reclaimed water (i.e., for direct crop irrigation) which will also have to be considered, and may make this option more costly or difficult to implement.

IMPLEMENTATION

The agency and stakeholder members of the Technical Advisory Committee should continue to meet as the Watsonville Sloughs Management Task Force to guide implementation of the Water Resources Management Plan and develop other efforts toward the potential future preparation of a comprehensive Watsonville Slough System Master Plan. Participating agencies should provide staff time for projects within their jurisdiction. Activities of the Task Force would include the following:

<u>Water Resources Plan Implementation</u> - Prioritize and oversee implementation of this plan's recommendations for site specific abatement efforts, water quality studies and additional coordinated monitoring, and flow management and augmentation studies.

<u>Wetland Management/Restoration Plan and Objectives</u> - Refine the recommendations of this plan into more specific overall objectives for water resources management; develop specific plans for wetland ecosystem protection and restoration throughout the slough system watershed, taking into account existing land uses and watershed activities; and subsequently implement these objectives and plans.

<u>Evaluation and Implementation of BMPs and Protection Policies</u> - Many of the source control BMPs are already being implemented by the County, City and landowners. The effectiveness and degree of implementation should be evaluated and augmented as needed. The following documents should be reviewed for adequacy with respect to protection of the slough system: city and county general plans, land development ordinances, and design criteria; the Monterey Bay National Marine Sanctuary's Water Quality Protection Plan; and the Central Coast Regional Water Quality Control Board's Basin Plan provisions.

<u>Implementation and Funding Mechanisms</u> - The task force should seek to identify and coordinate various funding mechanisms for this plan's implementation such as: state and federal grants and loans, drainage (stormwater district) fees, private grant funding, use of conservation easements, and mitigation measures for new development. The task force should also explore potential funding sources for a Watsonville Slough System Master Plan. While an overall master plan would ease coordination of comprehensive slough system resource management, it is not a prerequisite for the implementation activities listed above.

SECTION 2

INTRODUCTION AND BACKGROUND

The Watsonville Slough System is an extensive coastal wetland complex located in the southwestern corner of Santa Cruz County. The upstream portion of the slough system consists of a branching, interconnected network of primarily freshwater palustrine (emergent vegetation) wetlands, separated by a tidegate (and a pump) from the downstream portion. The downstream portion consists of a smaller coastal saltwater marsh (Watsonville Slough proper) which flows into the mouth of the Pajaro River. Watsonville Slough discharges runoff into the Pajaro River lagoon/estuary and then on to the Monterey Bay, which was designated a National Marine Sanctuary in 1992.

The slough system encompasses approximately 800 acres of flat wetland area, which drains a 13,000-acre watershed (see **Figure 2-1**). The slough system consists of six major branches: Watsonville Slough, Harkins Slough, Hanson Slough, Struve Slough, West Branch of Struve Slough (known as West Branch Slough), and Gallighan Slough. The biological values of the slough system have been acknowledged by numerous federal and state agencies, and the system have been designated as an "Area of Special Biological Importance" by the California Department of Fish and Game (CDFG). The sloughs have been identified by the federal Environmental Protection Agency (EPA) and the California State Water Resources Control Board (SWRCB) and others as a water body where beneficial uses have been impaired. The California Department of Fish and Game will soon be designating a 109-acre parcel between Lee Road and Highway 1 as an ecological reserve.

The slough system is located along the northern edge of the Pajaro Valley, one of California's major agricultural regions. The climate is mild and many types of row and berry crops are grown year-round within the slough system watershed. The watershed also includes approximately 2,400 acres of the urban area of the City of Watsonville and the town of Freedom. The sloughs receive runoff from a mix of urban, industrial, rural residential, agricultural and open space watershed areas.

The degraded water quality of the slough system has been documented by a number of studies, including those authored by Greenlee and Ricker (1981), Aston (1977), AMBAG (1982), the SWRCB Toxic Substances Monitoring Program (1991), an agricultural return flows study by Jagger (1981), as well as on-going monitoring by the California Regional Water Quality Control Board (RWQCB) and Santa Cruz County. High concentrations of pesticides and heavy metals from watershed activities have been cited as one of the most significant environmental problems of the slough system. These pollutants commonly adhere to sediments, such that erosion from agricultural fields and urban runoff plays a significant role in the transport of pollutants and water quality degradation of the slough system. Additionally, the low stream gradient and constricted outflow of the Watsonville Slough System to the Pajaro River Lagoon/Estuary contribute to poor water flow and circulation, compounding the water quality problems.

The sloughs are surrounded and impacted by many different types of land uses and their associated land and water management practices. Because of increased development pressure and long-standing agricultural encroachment on this area of biological significance, the AMBAG, with support from the

County of Santa Cruz and the City of Watsonville, is endeavoring to establish a management plan and program to appropriately manage, restore, and preserve the slough ecosystem and its water quality. The County of Santa Cruz unanimously approved a resolution mandating preparation of a master plan for Watsonville Slough System. They designated AMBAG as the lead agency for preparation of the plan. The City of Watsonville adopted a motion to support AMBAG in applying for a SWRCB 205(j) Water Quality Planning grant to fund the preparation of such a plan.

Questa Engineering Corporation was hired by AMBAG in May 1994 to conduct hydrological and water quality investigations of the Watsonville Slough System and to evaluate management practices for water quality improvement. This report presents the results of the water quality study along with recommended water management measures.

This project has been funded by a grant administered by the SWRCB under Section 205(j) of the Federal Clean Water Act. This section of the Act provides funds for planning studies that provide strategies to clean up water bodies that are impaired by non-point source pollution (i.e., polluted runoff) as well as assist in the reduction of this type of pollution. The information and recommendations from this project are intended to provide fundamental input for an overall Watsonville Slough System Master Plan, which has been proposed to be undertaken subsequent to this study, pending the availability of funding.

The purpose of the Management Plan was to: (a) investigate and develop baseline information on the hydrologic and water quality conditions in the slough system; (b) identify primary sources of non-point pollution entering the wetland areas; and, (c) evaluate and recommend alternative watershed management practices and other pollution control strategies to improve water quality while also enhancing the wetlands and water management in the system. The specific scope of this project, as specified in the contract between AMBAG and the SWRCB, was to prepare a Watsonville Slough System Water Resources Management Plan that will:

1. Identify the primary sources of non-point pollution entering the wetland areas.

2. Show rates of water movement and sedimentation and flood flows.

3. Include a prioritized implementation plan for improving water quality for wildlife and recreational use in the Watsonville Slough System, with evaluations of in-channel improvements to improve wetland removal of urban and agricultural pollutants, cost analysis of watershed and wetland BMPs, analysis of plant distribution, and improved water supply management.

4. Provide basic hydrologic information for the future development of the Watsonville Slough System Master Plan suggested by the County of Santa Cruz and City of Watsonville.

SECTION 3

PROJECT SCOPE AND APPROACH

The overall purpose of this study was to gather and analyze water quality, hydrologic and related environmental information for the Watsonville Slough System, and from this develop recommended management guidelines to integrate future water quality improvement, habitat restoration and water resources management activities in the watershed. The key elements of the study approach are described here.

3.1 PROJECT ORGANIZATION AND MANAGEMENT

The overall project was managed and administered by staff of the Association of Monterey Bay Area Governments (AMBAG). This included contractual arrangements and coordination with the State Water Resources Control Board and other involved agencies. AMBAG also administered the contract with the project consultant, Questa Engineering, and organized the activities of the Technical Advisory Committee (TAC) for the project. The TAC participated in the selection of the project consultant, and met quarterly during the project to review work progress and provide direction and input to the study. AMBAG also coordinated the public participation element of the study, conducting public meetings and distributing informational material regarding the project.

3.2 EXISTING INFORMATION

The large volume of existing water quality, hydrologic and physiographic information pertaining to the Watsonville Slough area was compiled and reviewed by AMBAG for use by the project consultant. This included present and historic information on wetlands and biological resources of the study area. Maps of sub-watersheds were also prepared to assess areal contributions of non-point source pollutants and review existing utilization and implementation of best management practices and ordinances.

3.3 HYDROLOGIC STUDY

A hydrologic study was conducted by the project consultant to define the overall occurrence and movement of water in the Watsonville Slough System. This provided the basis for evaluation of water resource management options and considered the spatial (i.e., geographical) and temporal (i.e., seasonal) differences in water sources and circulation patterns in the system. The key elements of the hydrologic study included the following.

Identifying Water Sources

The background hydrologic data and watershed mapping were reviewed and water sources (i.e., inputs) to the system were identified and characterized. Each sub-watershed area was defined and rainfall-runoff characteristics were evaluated. Areas of known groundwater and slough recharge were taken into account, as were existing land uses, vegetation, soil and geologic factors.

Water Budget

A general inflow-outflow water budget for the slough system was developed. The inflow-outflow water budget was completed for average conditions using monthly time steps. Inflow sources include surface runoff, direct rainfall, return flow from agricultural operations, septic system discharges and groundwater seepage. Outflow factors included pumped discharge, deep groundwater recharge, groundwater seepage and evapotranspiration. All available records were utilized in this analysis, including historic Shell Road pump station records, which provided the basis for model verification. Annual runoff from the ungaged watersheds was based on application of the Soil Conservation Service's Curve Number Method.

Water Management Practices

The existing inundation patterns of the sloughs were evaluated as affected by the operation of the terminal pumps, tide gates, and other drainage facilities. Operation procedures, pumping rates, and culvert dynamics were reviewed with respect to flooding, vegetation distribution, and water quality effects.

Sedimentation Rates

Erosion and sedimentation processes in the slough watershed were assessed. This evaluation was based upon available data, including historic air photos, topographic/hydrographic information, SCS supplied data, and personal accounts. A relative comparison of potential sediment sources, according to sub-watershed and land use activity, was made. Estimates were made by application of the Universal Soil Loss Equation for each sub-basin.

Water Management Objectives and Policies

A review was made of the various competing water interests and policies. The basic water interests covered were:

- Agricultural Uses
- Wetland/Water Quality Protection
- Mosquito Abatement Concerns
- Drainage and Flood Control

- Groundwater Management

For each competing water interest, the specific objectives, policies and/or requirements were reviewed and described. This provided the basis for subsequent consideration of the effects of various restoration or management options with respect to each water interest.

3.4 WATER QUALITY INVESTIGATION

A water quality investigation of the Watsonville Slough System was conducted, which included the following elements:

Quality Assurance Project Plan (QAPP)

A QAPP was first prepared in accordance with EPA Guidelines. The QAPP sets forth procedures for the collection and assessment of measurement and monitoring data, acceptable tolerances of accuracy, precision, completeness, representativeness, and comparability of the data. Prior to initiation of the field activities, the QAPP was reviewed and approved by the SWRCB staff.

Data Review

Sampling station location and frequency of water quality monitoring was determined based on review of historic information and the preliminary hydrologic inventory, and known or suspected water quality problems in the watershed. Winter stormwater sampling periods (to assess runoff) and summer periods (to assess low-flow pollutant build-up) were determined to be necessary.

Water Quality Monitoring

A water quality monitoring program was developed and carried out, adhering to the project QAPP. The monitoring included field measurements for pH, temperature, dissolved oxygen, turbidity, and conductivity, as well as laboratory determinations of ammonia, phosphate, nitrate, suspended and total dissolved solids, oil and grease, various heavy metals and several pesticide screens.

Water quality sampling efforts were conducted at the end of the dry season in September, 1994, and during fall-early winter runoff events in October, November and December, 1994. The data collection in this monitoring program were analyzed and compared with historic data to help establish appropriate water quality control needs and strategies.

3.5 WATER QUALITY MANAGEMENT RECOMMENDATIONS

Water quality management alternatives were identified, evaluated and prioritized focusing on measures to improve slough water quality, with an emphasis on cost-efficiency and realistically achievable methods. Improvement of water quality in the Watsonville Slough System is recognized as vital to the reestablishment of a high diversity of invertebrate life in salt marsh sections of the slough and areas degraded by fill. Implementation of watershed best management practices, ordinances regulating development and in-channel modifications were considered to improve and restore the Watsonville Slough System's aquatic habitats.

Water management alternatives considered the operation and maintenance of slough water control structures, such as tide gates, headworks pumps (used to actively remove ditch water during winter flooding or high tidal flows), ditches and drains. Consideration was given to agricultural and wetland management criteria.

The implementation plan for the water quality improvement and water supply management recommendations is intended to facilitate local jurisdiction implementation of policies, ordinances and programs to manage the Watsonville Slough System watershed issues. Specific tasks completed for this aspect of the study included the following:

Source Control BMPs and Wetland Restoration Alternatives

Source control BMPs and wetland restoration management alternatives for water quality improvement were identified in this sub-task. BMPs addressed urban, agricultural and rural residential land use activities in the watershed. Downstream alternatives included channel design modifications to permit in-channel vegetative growth (such as along low-flow areas or flood terraces), vegetative filter strips along channels, and water management modifications such as flow augmentation, tailwater recirculation and water level controls, which may allow in-channel vegetation establishment by control of depth, period, and frequency of inundation.

Feasibility Evaluation

Conceptual water quality management alternatives were screened for cost, effectiveness, and practicality. The degree to which various BMPs and other measures are currently in effect was reviewed.

Impacts of Water Management Measures

An analysis was made of the effect of various water management alternatives in regard to competing water interests and needs. This analysis considered estimated benefits and adverse impacts of each measure. The objective was to identify measures that will maximize the environmental benefits (to water quality wildlife and wetland values), while minimizing conflicts or problems from the standpoint of agricultural uses, mosquito abatement and storm drainage. A matrix analysis was used to weigh the pros and cons of each management measure against each competing water interest.

Water Quality Improvement Recommendations

Water quality improvement recommendations were developed and presented for review and discussion with the TAC. Recommendations were based on the concepts developed and screened in the prior tasks and were refined at this stage to include typical design elements, associated costs, and general areas of the sloughs where they would apply.

Implementation Plan

An implementation plan was prepared, identifying necessary capital improvements, training and educational programs, monitoring/maintenance needs, and the management agencies that would be responsible for overseeing operations, maintenance, and management programs. Also included in the implementation plan are potential funding sources.

3.6 DRAFT AND FINAL MANAGEMENT PLAN

Final Management Plan

A Draft and Final Management Plan (represented by this report) was prepared as the final task. The Management Plan reflects all comments and input received from AMBAG staff and the TAC.

SECTION 4

BIOLOGICAL RESOURCES

4.1 INTRODUCTION

The Watsonville Slough System is generally recognized as the largest and most significant wetland habitat between Pescadero Marsh in San Mateo County to the north and the Elkhorn Slough in Monterey County to the south. The slough system contains remnant but, nonetheless, significant areas of salt-marsh and brackish marsh, riparian and oak woodlands, dune and coastal scrub communities, bodies of open water, and perennial freshwater marsh and seasonal wetlands. The great diversity of habitats present within the relatively small watershed and its occurrence on the Pacific Coast flyway make the slough system especially important as a refuge, feeding and resting area for migratory, winter and resident waterfowl. The slough system also is reported to support the largest concentration of migrant and wintering raptors in Santa Cruz County (CH2M Hill, October 1990).

In addition to the waterfowl, shorebirds and song birds which inhabit the wetlands, there are a large number of the more common amphibians, reptiles, and small and large mammals. All of these species utilize the richly diverse habitat of the slough system.

The following discussion briefly describes the historic slough conditions, common plant and aquatic communities, as well as species which are rare or endangered that occur in the sloughs. This section was prepared based on compilation of readily available information from other studies. It should not be construed as a thorough survey of biological resources of the study area, which was not authorized or within the scope of this project.

4.2 HISTORIC CONDITIONS

During the last glacial era of about 17,000 years ago, sea level was about 100-feet below present sea level. This era had a historically wetter climate associated with heavy rainfall and consequently increases in surface runoff. The increased runoff allowed the ancestral streams of the Watsonville Slough System to cut channels and form narrow valleys in the adjacent older marine terrace deposits. As sea levels rose, following the post-glacial warming period, the valleys were inundated and deposition of clayey sediments occurred. These deposits are the blue clays which underlie the more recent slough deposits and cause the perching of groundwater which is largely responsible for the present day wetland characteristics.

The coastal landscape was also rising during this period (and continues to rise) which, during some periods, exceeded the rate of sea level advance. When the net effect of coastal rise exceeded the sea level, shallow freshwater marshes and accumulation of the plant remnants of the tules and other marsh plants formed the extensive peat deposits of Harkins and Struve Sloughs. Tidal marsh extended almost into the main Watsonville coastal plain, gradually transitioning to brackish and freshwater marsh and seasonal wetlands, eastward toward the vicinity of Watsonville. The alluvial deposits on this plain consist of dark and highly organic silty clays, resultant from deposits from both an estuarine environment and from riverine flooding from the Pajaro River during periods of heavy rainfall. Although peat deposits, including commercial quality deposits, are present in the subsurface in many of the sloughs, the actual present day slough surface deposits are largely organic rich silts and clayey sediments. This indicates that the slough systems were once highly saturated by flooded "bay" environments.

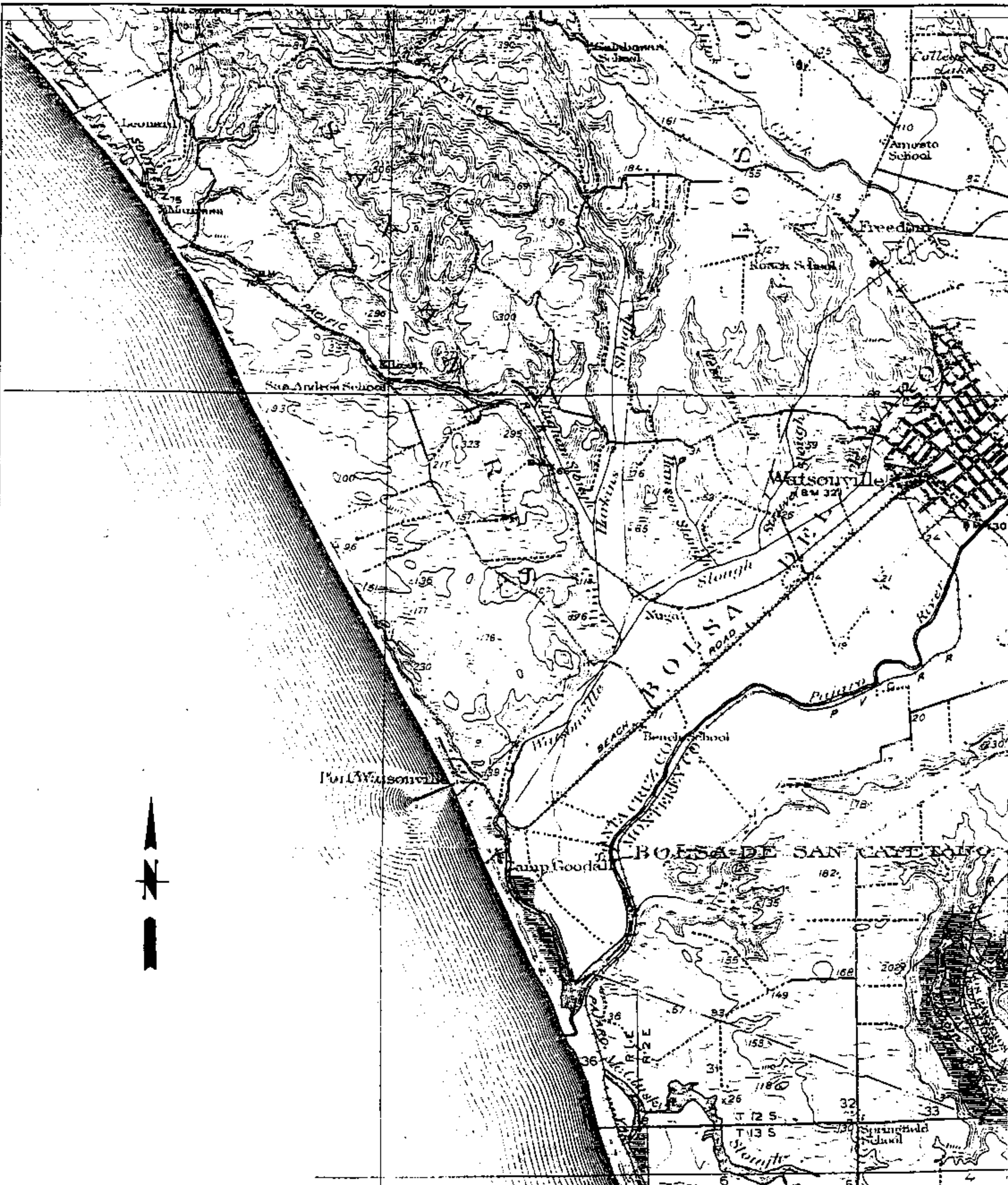
Much of the native flora of the slough system has been altered by agricultural activities beginning as early as the 1870s, so that one can only speculate about the historic conditions and extent of the wetlands. A concept of the approximate conditions of the Watsonville Slough System in the mid-1800s, as diagramed by Swanson (1992) is shown in **Figure 4-1** . The activities which significantly altered the slough system included the installation of the ditching system along the major sloughs, which serve to drain surface water and lower the water table within the branch sloughs, and the construction of the head works at Shell Road, which precluded significant tidal action above this point. Installation of subsurface tile drains also permitted many of the soils to be farmed on the Watsonville coastal plain. Without these drainage works, the area would have been too wet to cultivate these soils.

Some information useful in the reconstruction of historic conditions include the 1912 U.S. Geological Survey topographic map of the Watsonville area (see **Figure 4-2**), aerial photography of the watershed from the files of the U.S.D.A. Soil Conservation Service, and interpretation of the 1910 U.S.D.A. Soil Survey of the Pajaro Valley Area.

The historic topographic maps and the old soil survey indicates that lower Watsonville Slough was a tidal or brackish marsh to a point around the current San Andreas Road crossing, above the confluence of Harkins Slough. Saline estuarine soils are shown in a band following the present realigned slough in this area. Several slight meanders shown on the historic maps and visible as historic aerial photography, have been removed through strengthening of the slough in this area. Judging from current vegetation patterns in the lower slough, the plant community would have consisted of alkali bulrush in the lower elevation areas, with pickleweed and jaumea, alkali heath and saltgrass and saltbush appearing as elevations increased.

The slough bottoms were likely a diverse and complex vegetation mosaic. Dense stands of coast live oak would have blanketed the north and northeast sides of the sloughs. Riparian forest of willows and possibly alders were possible in upper slough bottoms. Bays and other deciduous shrub and tree species were probably found in the slightly drier margins of the slough edges. The riparian forests would have been interspersed with some small shallow open water areas, and large expanses of water loving grasses and grass-like plants such as tules, cattails, sedges and rushes.

Because of the distribution of highly organic clays and peaty soils in the sloughs, original plant cover may have been dominated by tules and grass-like plants with a willow fringe or mosaic . Such deposits typically are indicative of freshwater marshes where plant detritus accumulates and decays slowly under anaerobic conditions. Remnants of these plant communities can still be seen in various portions of the slough. Just as today, the slough system probably was responsive to annual variations



SCALE: 1" = 4 MILES

QUESTA ENGINEERING, CORPORATION POINT RICHMOND, CALIFORNIA	**WATSONVILLE SLOUGH SYSTEM** **1912 USGS TOPOGRAPHIC MAP**	FIGURE **4 - 2**

in rainfall, with vast expanses of shallow flooded areas and deeper open waters persisting throughout the summer months in wet years, and smaller areas of flooding and shorter duration ponding in dry years. The hills above the sloughs were likely coastal scrub/grassland phasing into oak savanna in the upper portions of the slough watersheds.

4.3 PLANT COMMUNITIES

A vegetation map showing plant communities of the Watsonville Slough System was prepared for this project by Lindsey Stevens as part of a senior thesis at U.C. Santa Cruz. The map was based on interpretation of 1992 1:12,000 color infrared aerial photography with extensive field checking. A generalized vegetation map of the watershed developed from this work is provided in **Figure 4-3**. Detailed mapping of wetlands or bottom land plant communities were abstracted from this map source and are shown on **Figure 4-4**. The plant communities were based on the classification system developed by Holland (1986). A description of several key plant communities are depicted in **Figure 4-4** as follows.

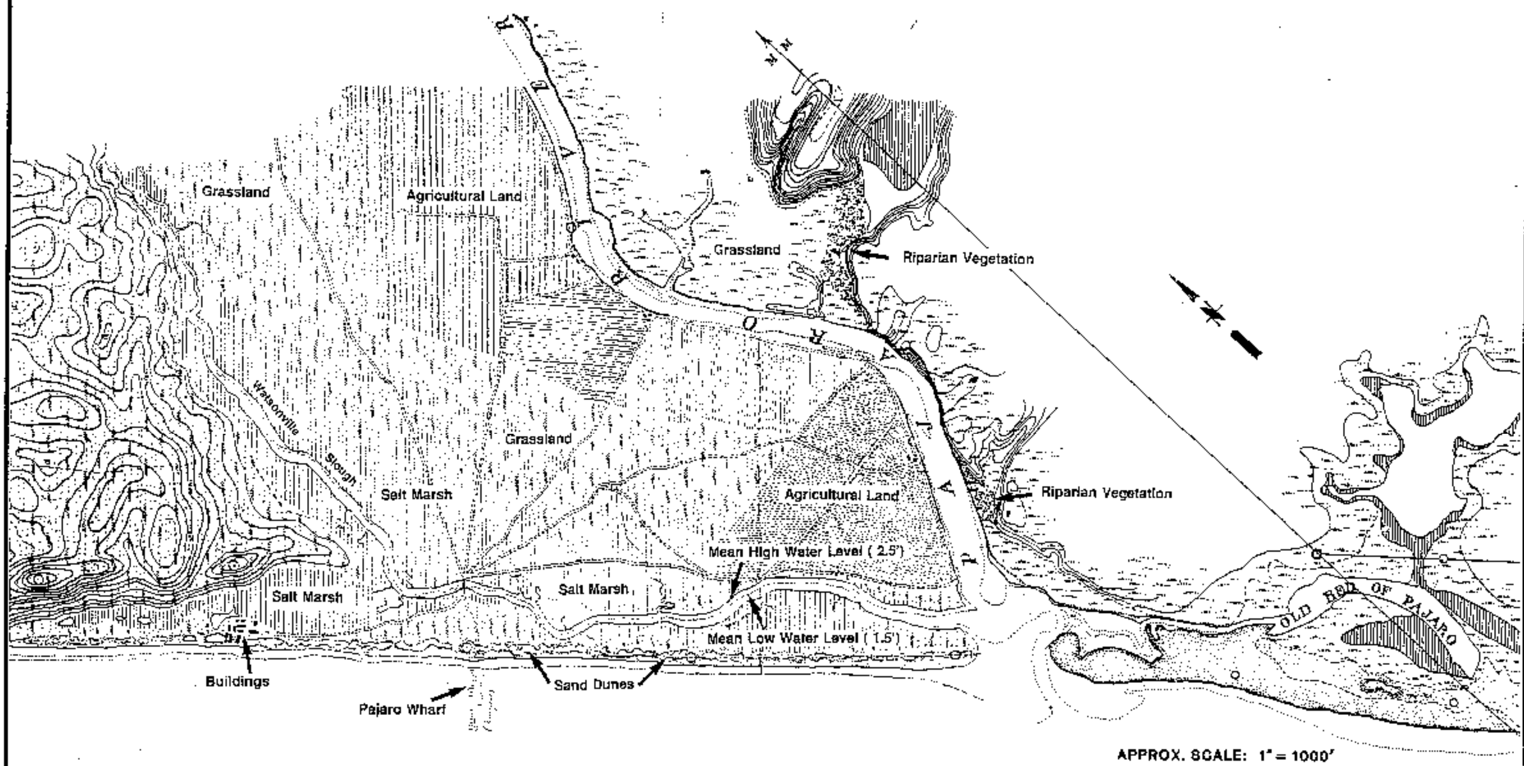
Northern Coastal Salt Marsh (SM)

The coastal salt marsh community occurs along the lower Pajaro River Lagoon, where it is a tidally influenced salt marsh, and in diked-off lands above the Shell Road headworks, where it is considered a brackish marsh. The tidal salt marsh supports pickleweed (*Salicorna virginica*) with some jaumea (*Jaumea carnosa*), alkali heath (*Frankenia salina*), and saltgrass (*Distichlis spicata*) in higher areas. The brackish marsh above Shell Road includes these same species with pickleweed in narrow bands along former meandering channels between levees, and the later transition zone plants on slightly higher ground which is flooded during winter months. Dense areas of poison hemlock (*Conium maculatum*) and common fennel (*Foeniculum rulgare*) occur on higher ground.

Salt marsh habitat is a valuable part of the ecosystem, but it is typically utilized by wildlife less extensively than freshwater marsh, as the low cover provides less shelter and protection from predators and the saline conditions and helophyte plants provide limited wildlife forage. Salt marsh does provide valuable cover for several small mammals and forage and nesting habitat for birds.

Open Water (WA)

Various bodies of open water are shown on the plant communities map. These represent conditions at the time of the aerial photography, May 1992. Open water provides breeding habitat to a number of amphibians, as well as feeding, resting and breeding habitat for water birds. Food sources within the ponds include small fish, invertebrates, seeds from emergent marsh plants growing in the ponds, pond weed, algae and tubers. Several water birds nest in the emergent marsh vegetation associated with water bodies. The largest of the freshwater bodies are in Harkins Slough and represent former peat mining pits that are flooded with intercepted groundwater. These are several acres in size and are deep (>five-feet) ponds, ringed by areas of shallower emergent marsh, willow forests and seasonal

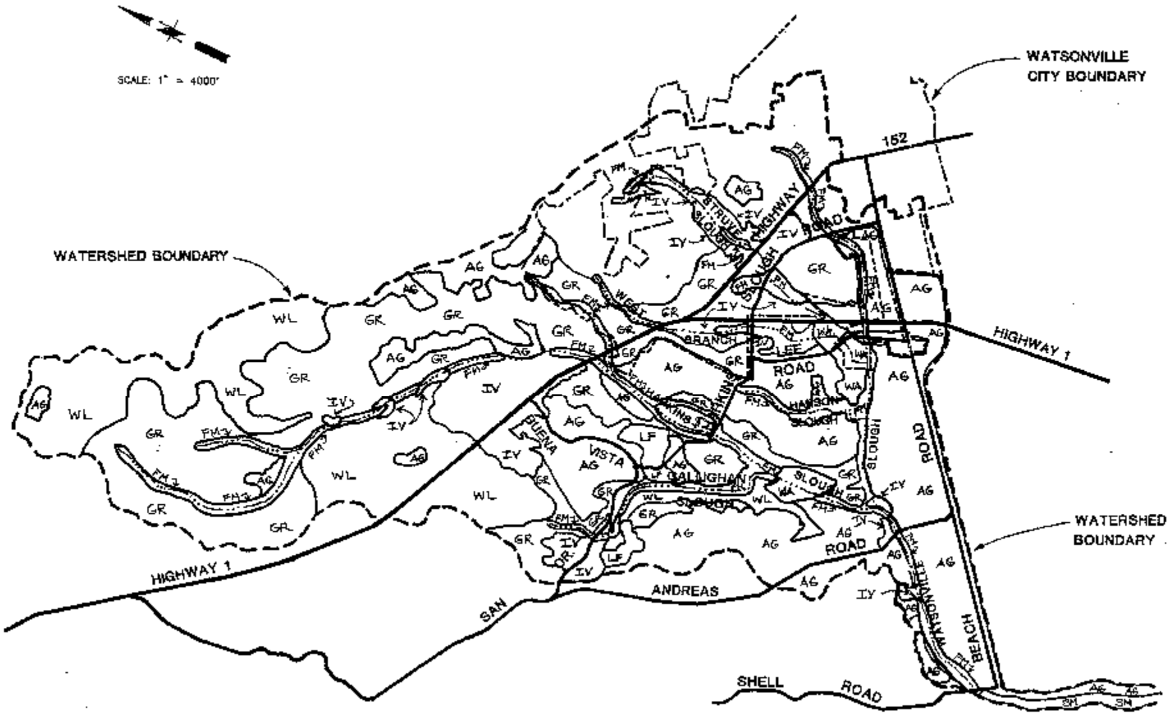


SOURCE: SWANSON & ASSOCIATES, 1992

QUESTA ENGINEERING CORPORATION
POINT RICHMOND, CALIFORNIA

1853 MAP OF THE PAJARO RIVER LAGOON AND WATSONVILLE SLOUGH AREA

FIGURE 4-1



LEGEND:

- AG - AGRICULTURAL AREA
- FM - FRESH WATER MARSH
- GR - GRASSLANDS
- IV - INTRODUCED VEGETATION, ie. POISON HEMLOCK, CURLY DOCK, DANDELION AND EUCALYPTUS TREES.
- LF - LANDFILL
- SM - SALT WATER MARSH
- WA - OPEN WATER
- WL - WOODLANDS

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WATSONVILLE SLOUGH SYSTEM
VEGETATION MAP (GENERALIZED)

FIGURE **4-3**

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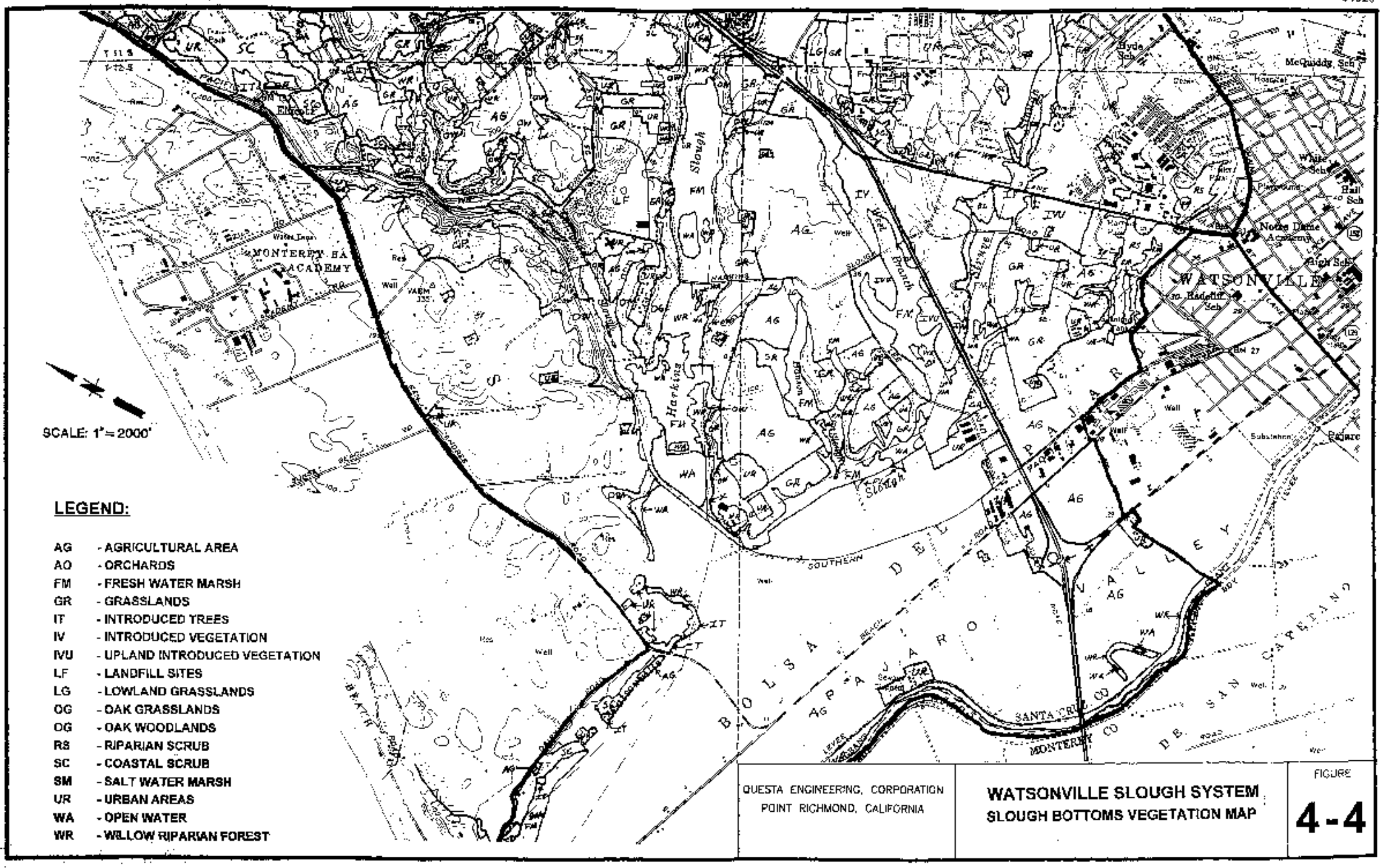

FIGURE 4-4
WATSONVILLE SLOUGH SYSTEM
SLOUGH BOTTOMS VEGETATION MAP

wetlands.

Throughout the slough system there are other open water bodies which are smaller and fluctuate seasonally. In a heavy rainfall year, such as 1982-83, 1986 and 1995, more than three-quarters of the slough systems are inundated with water depths ranging from less than one foot to three feet. Although water levels recede slowly during the spring, in wet years there are large persistent ponds which can extend into August. In dry years, such as the period from 1987 to 1992, water levels and associated ponding in the slough system is reduced, perhaps to one-tenth or less of the slough bottoms between the winter and summer months. In dry years water levels recede rapidly and are dry by late May. It would be expected that the aerial extent of the freshwater wetland plant community expands and contracts in response to cycles of precipitation (i.e., areas of cattails or willows may expand). The Pajaro Lagoon represents a large area of salt to brackish open water that also is seasonal in character, particularly in regard to water quality and salinity levels (as discussed in **Section 5**).

Freshwater Emergent Marsh (FM)

The freshwater emergent marsh (FM) plant community is the most diverse and complex within the slough system. The species composition of this community tends to be stratified by elevation into zones corresponding to the preference or tolerance of the plants to depth, time and duration of inundation or saturation. The community is dominated by herbaceous vegetation and emergent marsh plants adapted to conditions of perennial or seasonal inundation and high soil saturation.

In areas with shallow, ponded water, the vegetation mosaic includes dense areas of tules (*Scirpus spp*) and cattails (*Typha latifolia*). These can form dense impenetrable clumps. Lower elevation areas, above areas that regularly pond water, are occupied by several smartweed (*Polygonum*) species, sedges (*Carex spp.*), rushes (*Juncus spp.*) and pacific silverweed (*Potentilla anserina*). These species are typically found at elevations between about two and four feet above mean sea level (MSL). A mixture of water tolerant annual grasses and weeds occur on slightly higher ground, also typically between elevations two and four feet MSL. These areas flood during periods of heavy rainfall and are transitional to seasonal wetlands. Among the common water tolerant weeds are cocklebur (*Xanthium strumarium.*), curly dock (*Rumex crispus*) and wild radish (*Raphanus sativus*). Scattered arroyo willow may be interspersed.

Waterfowl are abundant throughout the Watsonville freshwater marsh complex. In fact, for many species, the Watsonville Slough System's winter counts of waterfowl can rival or even surpass those noted for the highly productive Elkhorn Slough to the south (Busch, 1985). In addition to migratory waterfowl, migrating rails, herons and other bird species use the emergent marsh portions of the slough system during migration and for over wintering.

Among the bird species known to breed in the slough system are the mallard, cinnamon teal, gadwall, ruddy duck, American coot, pie-billled grebe, green heron, great egret, snowy egret, black-crowned night heron, Virginia rail, sora, common gallinule, and long-billed marsh wren (County of Santa Cruz, 1981). American bitterns courtship behavior has been observed in slough areas and may breed in the slough system (Busch, 1985).

Coastal wetlands are well known to be very important to migratory and wintering waterfowl, which make use of shallow and deep open water areas and adjacent emergent marsh. Ideal habitat conditions for breeding waterfowl is a ratio or mix between 1:1 and 2:1 emergent vegetation to open water. In addition, the depth and seasonality of ponded water is very important.

Resident waterfowl inhabiting freshwater marshes such as mallards, cinnamon teal, herons and rails are dependent upon permanent open water during summer months. During dry years, in particular, resident bird populations are somewhat limited by the lack of more extensive areas of permanent open water. In fact, many of the waterfowl leave by spring as water levels begin to drop in the sloughs.

Central Coast Arroyo Willow Riparian Forest (WR)

The riparian forest habitat occurs as scattered remnants throughout the slough complex. It is dominated by the presence of arroyo willow (*Salix lasiolepis)*, creek dogwood (*Cornus californica*), elderberry (*Sambucus mexicana*), blackberry (*Rubus ursinus*) and poison oak (*Rhus diversiloba*). Some areas have coast live oak (*Quercus agrifolia*) intermixed, but more often the oak is on the upland slopes just above the slough bottoms.

Cottonwoods, sycamores, box elder and alders were likely once part of the historic mixed deciduous riparian forest in at least parts of the slough system. Except for scattered specimens, these trees were largely removed when the sloughs were converted to agriculture and pasture. Only the pioneering willow has returned in any significant numbers. Rapid regrowth and expansion of the willow community is occurring in many parts of the slough system, most notably Gallighan and Harkins Sloughs.

The willow-dominated riparian forests of the slough system presently lack the species diversity and structural complexity most desirable for wildlife habitat. For instance, there are few taller, higher canopy trees which are important for raptors. Nor are there any decadent snags which provide habitat for cavity nesting birds. However, the willow stands likely provide good habitat for a number of songbirds.

A large number of wildlife species utilize riparian forests. Riparian forest habitat provides essential feeding, cover and nesting sites for many bird species, particularly migratory birds (non-waterfowl) and raptors. Birds which utilize this habitat in the Watsonville Slough area include the northern oriole, Pacific-slope flycatcher, several sparrow species, chestnut-backed chickadee, Hutton's vireo, warbling vireo, bush tit, ruby-crowned kinglet, Swanson's and hermit thrushes, wren tit, yellow-rumped warbler, lesser and American goldfinch, and yellow, orange-crowned and Wilson's warblers. Riparian trees may also serve as nestings sites for buteos and acipiters, including Cooper's hawks and Redtail hawks.

Amphibians are also strongly associated with riparian habitats due to the proximity to freshwater and a moist micro-climate. All amphibians, by definition, require water for a portion of their life cycle. The red-legged frog and yellow-legged frog, both species of special concern, may be found along permanent water channels associated with riparian areas. The Pacific tree fog, newts and the Santa Cruz long-toed and tiger salamanders may also be found in some riparian habitats, provided other components of their required habitat, such as ponds and grassy areas, are also nearby.

Although many reptiles do not require moist environments, garter snakes, ring-neck snakes and alligator lizards prefer these environments. Riparian habitat also provides food, shelter and water for various small mammals. Racoons, striped skunks, ornate shrew, and brush rabbits forage near streams and slough channels and deer may come to these water sources to drink.

Coastal Oak Woodland (OW)

The woodland community occurs on the slopes above the slough bottoms and is best expressed as protected, with moist north and east exposures. Coast live oak (*Quercus agrifolia*) is the tree which defines this community. Other species include California bay, black oak, California buckeye, and some madrone. The coastal oak woodland is often dense with a complete or nearly complete canopy cover. It typically has an understory of coffeeberry, poison oak, other shrubs and ground cover plants. Areas of coast oak woodland are scattered throughout the Watsonville Slough System, but are widespread and best represented in Harkins Slough.

Oak woodlands provide valuable habitat for a large number of wildlife species. A number of bird species, such as the acorn woodpecker, use acorns in their diet, while others, such as the chestnut-backed chickadee, plain titmouse, white-breasted nuthatch, and brown creeper, feed on insects associated with oaks. Oaks also provide nesting habitat for many birds, and dead snags provide habitat for cavity nesters.

Woodrats, gray fox squirrels, and other small mammals are closely associated with woodland habitat. Many other mammal species, such as deer and bobcats, among others, also use the surrounding grassland and shrub communities. Gopher snakes, rattlesnakes, western fence lizards and northern alligator lizards, are also common at edges and openings in oak woodlands. Amphibians are generally uncommon in this woodland type. Amphibians such as newts and salamanders are common in oak woodlands during the winter months. The dense vegetation affords good habitat for woodrats and other small mammals. The presence of several dominant tree species and a well-developed understory provide vegetation, structural diversity and result in a relatively high diversity of wildlife species within this habitat.

Lowland Grasslands (LG)

This community found on the bottom lands of many of the sloughs is characterized by seasonal wetlands dominated by annual and perennial grasses, and herbaceous vegetation. In many places grasslands represent a transitional or ecotone community between freshwater marsh and adjacent grasslands on the upland side slopes of the sloughs. Many areas have been grazed or historically farmed. These activities, in conjunction with the alteration of the slough hydrology by sediment deposition, drainage channels, and pumping, have significantly altered the historic species composition of the community.

In many areas, the seasonal wetlands appear to be flooded and high groundwater tables have saturated surface soils in years of normal rainfall into the spring and summer months. Species observed in areas of seasonal wetlands/grasslands include annual bluegrass (*Poa annua*), perennial ryegrass (*Lolium perenne*), rush (*Carex ssp.*), wiregrass (*Juncus*) with some areas of a native creeping or alkali ryegrass (*Leymus ssp.*). Many animal species forage in the grasslands. Sparrows and goldfinches feed on the seeds of grass and thistles, whereas horned larks, western kingbirds, and western bluebirds forage on the many insects that inhabit grasslands. Hawks are often seen soaring above the grassland in search of prey. Ground squirrels, pocket gophers, voles and several species of mice are common inhabitants of grasslands, and deer browse the grasses and forbs. Lizards and snakes are common reptiles, and although amphibians are rare in the dry grassland, tiger salamanders may use abandoned burrows as refuge.

Grasslands provide valuable habitat for a variety of rodents and predators, including the burrowing owl. Grasslands are important feeding areas for kestrels, kites, barn owls, and loggerhead shrikes (Busch, 1985). Western meadowlarks breed and winter in the grasslands.

Raptors which are attracted to grasslands for the small mammals and seed eating birds common there include Peregrine falcon, a federal and state listed endangered species, and Cooper's and sharp shinned hawks (Busch, 1985), both state species of special concern.

4.4 MAMMALS

A number of small mammals forage along the slough channels and remnant woodlands including raccoons, muskrats and opossum. Other mammals active at the edge between the grassy uplands and wetlands include striped skunk, weasel, brush rabbit, blackmail jackrabbit, and the California ground squirrel. The grasslands are also important hunting and foraging habitat for such predatory mammals as the gray and introduced red fox, long-tailed weasel and coyote. These species would utilize gophers, ground squirrels, mice and voles, which inhabit the grasslands and seasonal wetlands. California blacktail deer, resident in the wooded portions of the Larkin Valley also would utilize the oak woodlands, grasslands, and coastal scrub uplands of the watershed.

4.5 AQUATIC HABITAT AND FISHERIES

The native fish of the streams and sloughs tributary to Monterey Bay include western suckers, hitch, squawfish, roach, speckled dace and scuplins. Other fish were introduced purposely by the State, as well as inadvertently by bait fisherman. These have included exotics such as carp, mosquito fish, golden shiners, and threadfin shad. When the mouth of the Pajaro River is open to Monterey Bay, marine species such as striped bass, starry founder, and marine bait fish travel into the tidal lagoon.

Watsonville Slough Estuary (Pajaro River Lagoon). Aquatic habitat and water quality conditions as they affect fisheries vary significantly seasonally in the Watsonville Slough Estuary which is a branch of the Pajaro River Lagoon, depending upon whether the mouth of the river is open to tidal circulation, or closed and blocked by a sandbar. This sandbar is often artificially breached by bulldozer when lagoon water levels get too high.

Marine fish populations are expected to be abundant and diverse, particularly in the winter when the mouth is open. Pacific herring, topsmelt, shinner perch, staghorn sculpins and the federally listed endangered tidewater goby, were the most abundant fish recorded in an early summer 1991 survey (Swanson, 1992). Striped bass were also common in late summer 1991. Steelhead trout likely use the lagoon for juvenile rearing and growth prior to entering Monterey Bay.

After sandbar closure in mid to late summer, and in years when the sandbar is not opened, the lagoon becomes brackish to freshwater, with periods of low dissolved oxygen and periodic aquatic habitat stresses imposed by possibly toxic agricultural inflows, and elevated temperatures or stratified salinity conditions. In years of significant freshwater conditions, freshwater fish species such as carp, hitch, Sacramento sucker, Sacramento blackfish, and Sacramento squawfish could utilize the lagoon.

Watsonville Slough System. The aquatic resources of the freshwater portion of the sloughs is diverse and varies with water levels. No sampling or inventories were completed for this project, however, it would be expected that a diverse group of aquatic insects and water warm freshwater fish could be found. Typical aquatic invertebrates would include emergent insects such as mayflies, caddisflies and mosquitoes. Other invertebrates may include water striders, whirling beetles, water boatman and numerous other species.

Fish species would be expected to occupy the lower and middle reaches of Watsonville and Struve and Hanson Sloughs, as well as the open water areas of Harkins Slough, where there are deeper ditches and ponds. Because of high summer temperatures and stagnant water conditions, the upper Watsonville Slough System supports warm water fish species with little or no significant sport fishing. Fish species recorded in the slough channels include Sacramento blackfish, brown bullhead, carp, goldfish and several types of sunfish (Cooling, 1984).

4.6 SPECIES OF CONCERN

A number of sensitive species or species of special concern are also known to inhabit localized portions of the watershed. Species of special concern include those plants and animals that are either listed, proposed to be listed, or candidates for listing by the U.S. Fish and Wildlife Service under the Federal Endangered Species Act, or by the State of California under its endangered species laws. Other sensitive species include:

1. Plants on the California Native Plant Society's rare and endangered plant list;
2. Birds protected by the Federal Migratory Bird Act; and,
3. Plants and animals on the California Department of Fish and Game's list of Species of Special Concern.

Several threatened or endangered species are known or expected to inhabit upland and wetland portions of the slough. A literature search and review of the California Natural Diversity Data Base (CNDDB, 1995) was conducted to determine known or suspected occurrences of sensitive species and species of special concern within the Planning Area. **Table 4-1** provides a list of special status species potentially occurring with the Watsonville Slough System. The following summarizes information on the specific species expected or known to occur or make significant use of habitats within the Watsonville watershed.

Several species that are listed in the CNDDB have narrow habitat requirements that would preclude their occurrence within the watershed. Monterey spineflower (*Chorizanthe pungens* var. *pungens*) is a coastal dune species at Manresa State Beach in the northwest portion of the project area. Monterey spineflower also occurs near the mouth of the Pajaro River. Robust spineflower (*Chorizanthe robusta* var. *robusta*) is known at Manresa State Beach and Sunset State Beach.

The tidewater goby (*Eucyclogobius newberryi*) is a brackish-water fish that is known to occur at the Pajaro River mouth and, therefore, is likely present in the estuarine portion of Watsonville Slough. The monarch butterfly (*Danaus plexippus*) is known to mass during winter on certain trees or groves of eucalyptus trees along the Santa Cruz County and Monterey County coastline and at Manresa State and Palm Beach. Within the planning area, the monarch is known to occur at the west end of Beach Road. The western snowy plover (*Charadrius alexandrinus novosus*) is known to inhabit the tidal marsh at the Pajaro River mouth and, therefore, is also likely to occur in the estaurine portion of Watsonville Slough. The black legless lizard (*Anniella pulchra nigra*) primarily uses sandy coastal dune habitats and may potentially occur in the coastal sand dune areas bordering the watershed to the west.

The following sensitive species and species of special concern have potential for being present in the project area based on required habitat.

Tidewater Goby (*Eucyclogobius newberry*)

The Tidewater goby is a federally listed endangered species that potentially occurs within the lower tidally influenced portion of the Watsonville Slough System. Tidewater gobies are typically found in salt to brackish water estuaries along the West Coast. Tidewater gobies can be found in seasonally closed river mouths along the Central Coast. These gobies can be found in other Santa Cruz locations, such as the Waddell Creek and the Scott Creek lagoons. The goby has the ability to withstand fluctuations in temperature and salinity in habitat. Historically gobies likely inhabited the Pajaro River Lagoon system.

Santa Cruz Long-Toed Salamander (*Ambystoma macrodactylum croceum*)

The Santa Cruz long-toed salamander is listed as endangered by the U.S. Fish and Wildlife Service (USFWS) and by the State of California. This salamander is known to occur at only 11 locations between Aptos, Santa Cruz County and Castroville, Monterey County (Ruth, 1994). Several breeding populations are known to exist in the project area, including Ellicott pond near Galligham

TABLE 4 - 1
SPECIAL STATUS SPECIES POTENTIALLY OCCURING WITHIN PROPOSED URBAN LIMIT LINE

Species		Status	Preferred Habitat
Plants:	Santa Cruz tarplant	FC[1], SE	Grassland
	Gairdners yampah	FC[2]	Grassland
Wildlife:	Santa Cruz long-toed salamander	FE, SE	Wetland, riparian, oak woodland
	California tiger salamander	FC[2], SSC	Wetland, grassland
	Western pond turtle	FC[2], SSC	Wetland, riparian, oak woodland
	Black-crowned night-heron	SA	Wetland, riparian
	California red-legged frog	FC[2], SSC	Wetland
	Black-shouldered kite	CP	Wetland, grassland
	Northern harrier	SSC	Wetland, grassland
	Burrowing owl	SSC	Grassland
	Short-eared owl	SSC	Wetland, grassland
	Tricolored blackbird	FC[2], SSC	Wetland, grassland, riparian
	Golden eagle	SSC	Grassland
	Ferruginous hawk	FC[2], SSC	Grassland
	Merlin	SSC	Grassland, wetland
	Peregrine falcon	FE, SE	Wetland, grassland
	Loggerhead shrike	FC[2]	Grassland
	Horned lark	FC[2]	Grassland
	Yellow warbler	SSC	Riparian
	Steelhead	SA	Streams

Status Explanations:
- FE: Federally listed endangered
- FC: Federal candidate
  - [1]Category 1
  - [2]Category 2
- SE: State listed endangered
- SSC: State species of special concern
- CP: California fully protected
- SA: Special Animal (Species listed by CNDDB as Special Animals, but not designated as protected under other categories listed above)

Sources: California Department of Fish and Game (CDFG) Natural Diversity Data Base (NDDB); 1975 Conservation Element of Watsonville General Plan; Final Environmental Impact Report for the Villages, October 1990; Draft and Final Subsequent Environmental Impact Reports for the Franich Annexation, September 1989 and May 1991; The Habitat Restoration Group.

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Source: Watsonville 2005: General Plan EIR, CH2MHill, 1992

Slough and the Buena Vista site near the intersection of Larkin Valley Road and Buena Vista Drive (M. Fusari, reported in Stevens, 1995). Long-toed salamanders spend much of the year below ground in groves of willows or other riparian vegetation, coastal scrub, or coast live oak woodland habitats. Following rains in early to late winter (November to February), adult salamanders migrate during the night to temporary or semi-permanent ponds to breed. After breeding, adult salamanders may remain in the vicinity of the breeding pond for a year or more before returning to their terrestrial retreats. Eggs hatch within 15 to 30 days. The larvae transform into juvenile salamanders in approximately 90 to 150 days, and reach sexual maturity after two to three years. Drainages with dense vegetation cover are preferred as a migration corridor. Dense vegetation is also required near or adjacent to breeding ponds, which serve as refuge for juvenile salamanders. The Santa Cruz long-toed salamander is also thought to occur in the Struve Slough area. There is potential for occurrence of this salamander at several of the semi-permanent small ponds and wetland areas within the project area.

With respect to pollution effects, local and nationally-known heptologists (Dr. Stephen Ruth and Dr. Mark Jennings) have expressed concerns about direct lethal and sub-lethal effects on the salamander from the use of the locally-used mosquito abatement chemical - Golden Bear 11-11 oil. No research has been completed to determine lethal doses for West Coast salamanders or possible sub-lethal effects; but there is a strong concern in the scientific community about potential effects on endangered amphibians. Research hepatologists suggest avoiding the use of this mosquito abatement spray in or near potential salamander habitat until more definitive research findings are available. They are also concerned about the use of mosquito fish in the system due to the potential predation by mosquito fish on salamander and red-legged frog larvae.

California Tiger Salamander (*Ambystoma tigrinum californiense*)

This salamander is a candidate (List 2) for federal endangered species status and is a California species of special concern. The California tiger salamander occurs in coastal and central California from Santa Cruz and the Sacramento Valley south to Santa Barbara. A small breeding population exists at Ellicot Pond and suitable habitat may be present in Struve Slough. Similar to the Santa Cruz long-toed salamander, adults spend much of their lives underground in terrestrial uplands. They migrate to breeding ponds during rainy nights in the period from November to February. Tiger salamanders are restricted to locations where breeding ponds are surrounded by suitable upland grasslands. After breeding, they return to the grassland areas (up to a half mile away), where they find refuge in abandoned rodent burrows. These salamanders are not usually found in ponds which have populations of bullfrogs (*Rana catesbeiana*) and introduced warm water fish (such as mosquito fish), which predate the eggs and young.

California Red-legged Frog (*Rana aurora draytonnii*)

The red-legged frog is a candidate (List 1) for federal endangered species status and is a California species of special concern. Its habitat includes permanent freshwater ponds, marshes and slow-moving streams, preferring sites with extensive emergent vegetation or other dense cover along the water's edge. Red-legged frogs are usually absent where bullfrogs or introduced predatory fish are present. Red-legged frogs are conceivably present in the larger ponds and wetlands associated with former peat mining in Harkins Slough.

Southwestern Pond Turtle (*Clemmys marmorata pallida*)

The Southwestern pond turtle is a federal category 1 candidate and a California species of special concern. It is a subspecies of the western pond turtle (*Clemmys marmorata*). The Southwestern pond turtle occurs in coastal hills and valleys west of the Central Valley from San Francisco south to the San Diego area. The southwestern pond turtle is known to occur in similar habitat in Elkhorn Slough in Monterey County and potentially may be present in the larger ponds associated with former peat mining in Harkins Slough.

Tricolored Blackbird (*Agelaius tricolor*)

The tricolored blackbird is a candidate for federal endangered species status (List 2). It is a colonial-nesting species, primarily restricted in distribution to California. The species occurs at scattered locales during the breeding season, inhabiting ponds, lakes or marshes with dense growths of tules and cattails. Populations are more widespread during the non-breeding season, when large flocks take advantage of food sources in agricultural fields and upland habitat. This species is threatened by loss and alteration of breeding habitat. Two nesting colonies have been identified in the project area west of Highway 1, one at Hanson Slough, the other at Struve Slough.

Black-Shoulder Kite (*Elanus leucurus*)

This small raptor is a fully protected species by the State of California. A small breeding population occurs in Santa Cruz County. The riparian forests of Harkins Slough are historically the principal breeding area within the County. Nesting locales include upper Watsonville Slough, Harkins Slough and Hanson Slough.

Santa Cruz Tarplant (*Holocarpha macradenia*)

The Santa Cruz tarplant is a state-listed endangered species and is a candidate (List 1) for federal endangered species status. It is typically found on sunny grassland areas with summer fog and gentle slopes. Soils are often poorly drained heavy clays on marine terraces. Once commonly distributed in coastal areas and throughout the San Francisco and Monterey Bay region, the Santa Cruz tarplant is now known to occur from 13 populations in the Monterey Bay area and from three sites in Contra Costa County. It is estimated that 90 percent or more of the remaining Santa Cruz tar plants occur within the Watsonville Slough System watershed (*personal communication - R. Morgan, Botanist - CNPS at 10/29/95 TAC meeting*) Known populations within the planning area include a grassy field just south of the Watsonville Airport and the County Fairgrounds property, and within an area immediately east of State Route 1 between Harkins Slough Road and West Beach Streets, among others.

Thorough surveys should be completed for all federally listed and candidate species prior to implementation of any project resulting from this plan that could affect a sensitive species. Supporting documentation of such surveys should be provided to the U.S. Fish and Wildlife Service. Specific mitigation measures should be proposed to minimize harm and offset the potential loss of all Federal endangered, threatened, proposed, and candidate species and their associated habitats. To determine whether the mitigation efforts are successful, mitigation measures should be implemented prior to any project activity.

4.7 DEGRADED WETLAND AREAS WITHIN THE WATSONVILLE SLOUGH SYSTEM

An aim of this project was to coordinate water quality improvement with measures to enhance or restore degraded wetland and riparian habitat in the Watsonville Slough System and highlight the degraded areas within the slough complex that would be considered candidate areas for restoration efforts. The identification of degraded areas was based on field studies and mapping provided by Lindsey Stevens, along with observations made during water quality monitoring and reconnaissance surveys of the watershed by the Questa study team.

Areas within the slough system were judged to be degraded based on the observation of one or more of the following: (1) invasive or exotic species dominant the channel and slough bottom area; (2) land use encroachment has significantly reduced or eliminated wetland and/or channel habitat; (3) blanketing of wetland vegetation due to sedimentation; and, (4) removal of vegetation. **Figure 4-5** shows the main areas of the sloughs where degraded wetlands are evident.

Invasive species degrade the slough habitat by crowding out or out-competing native species. Disturbance aids in the exotic plant establishment. Exotic plants do not normally provide suitable food sources and/or habitat for local wildlife. One good example is the establishment of Poison Hemlock within some of the sloughs. Poison Hemlock, a native of Europe and West Asia, was introduced as a garden plant. The plant competes very well with native species; however, the plant produces alkaloids which are toxic to most animal species. Hemlock can be eradicated through properly timed, once-a-year mowing, over a two-year period.

Land use encroachment has degraded large areas of the sloughs. Farming in and around the sloughs has been conducted since the early 1900s, and most of the sloughs have been channelized, drained and used for agricultural production. At present only portions of the slough areas are used for agriculture. Some sections have been abandoned long ago and have returned to a semi-natural state. Most of the encroachment in the sloughs is a result of intensive agricultural production immediately adjacent to the sloughs, leaving little or no buffer between crop land and slough channel. The lower portions of Watsonville, Harkins, and Struve Sloughs have been impacted to the greatest degree. In these areas, the slough has been fundamentally altered both from a vegetation and hydrology perspective and all that remains is a trapezoidal channel with little or no vegetative cover. Additionally, some of the earthen drainage channels may have been dug in areas that were not formerly slough wetland areas."

The upper portions of the slough system have been impacted by land use, but to a lesser degree than the lower sections. Portions of Harkins Slough, above Harkins Slough Road, have been altered by grazing animals and channelization of the slough. While agriculture has been a dominant land use in the watershed for over a century, the slough system is currently becoming more urbanized. Urban uses can have deleterious effects on the slough system that are different than agriculture that may irreversibly alter the system's environmental health or ability to function; and, as urbanization increases, impacts associated with urban uses may increase or expand. For the most part, the urban areas of Watsonville have been set back from the slough bottoms consistent with Department of Fish and Game recommendations, which may or may not be adequate for protection of the slough system. Small portions of the headwaters of the sloughs have been developed with shopping centers, trailer parks and residences; but urban development has generally proceeded along the ridge lines that divide the sloughs. Also, in a positive vein, the urbanization process has resulted in: (a) reclaiming lost wetland from agricultural use (e.g., Struve Slough near Main Street); (b) dedication of slough land for open space (e.g., Willow Creek Subdivision, Crossroads Shopping Center, etc.); (c) implementation of erosion and runoff controls (for nearly all new development projects); and, (d) slough enhancement through revegetation with native species in new development in conjunction with the California Department of Fish and Game (e.g., Crossroads II).

Some portions of the sloughs are degraded due to flooding and stagnant water conditions which is accompanied (or caused by) sedimentation. These areas are located upstream of many of the road crossings such as Lee Road and Harkins Slough Road. Erosion from the watershed combined with possible settlement of the roads has caused the culverts to fill with sediment, greatly restricting the natural drainage and water flow through the wetland area. Shallow water trapped in these areas can become stagnant, warm and produce nuisance, aquatic growths. Metals and other pollutants concentrate in these areas during the dry season. Mosquito breeding and odors also can be problems in these poorly drained areas. However, it is not universally agreed that these conditions constitute degraded wetlands; some people and organizations involved with wetlands management in the Watsonville Slough System believe these conditions are beneficial to overall wetlands restoration and enhancement goals for the area by virtue of the flooded conditions they create, regardless of water flow and circulation.

In the lower portions of the sloughs, especially Watsonville Slough and Harkins Slough, vegetation removal and dredging has a large impact on wetland habitat. Periodically, the channel is partially dredged by the Santa Cruz County Department of Public Works to maintain channel conveyance and flood control. This activity removes most if not all, of the vegetation in and around the channel and also causes temporary suspension of sediments and associated pollutants.

SECTION 5

HYDROLOGIC STUDY

5.1 WATERSHED CHARACTERISTICS

The Watsonville Slough System is an extensive coastal wetland complex, containing the largest contiguous wetlands area in Santa Cruz County. The sloughs are located in the southwestern corner of Santa Cruz County between the ocean mouth of the Pajaro River and the City of Watsonville. The slough system is an interconnected series of primarily freshwater, palustrine wetlands separated from a smaller coastal salt marsh by a headworks with pump station and tide gates near the ocean. The various branches of the slough system include Gallighan, Harkins, Hanson, West Branch, Struve, and Watsonville Sloughs - collectively referred to as the Watsonville Slough System. The wetland complex is a regionally significant habitat area for numerous species, including waterfowl, rodents, amphibians, and seed-eating birds. The rich prey base supports a very high diversity of raptors, herons, and other predators.

The freshwater and tidal marshlands of the Watsonville Slough System and the Pajaro River have been identified in studies by the California Water Quality Control Board, Central Coast Region (Regional Water Board), and other agencies as impaired water bodies with adversely affected wildlife and recreational uses. Although the Watsonville Slough System's wetland habitats are designated for protection by numerous federal, state, regional, and local programs, the sloughs' significant wildlife populations - including several Candidate Species for the Federal List of Threatened or Endangered Species, numerous Species of Special Concern and Locally Unique species - continue to be impacted by polluted runoff, drainage practices, and watershed land uses.

Climate and Topography

The Watsonville Slough System is located in southern Santa Cruz County, on the northern edge of the Pajaro Valley of Central California, adjacent to Monterey Bay (approximately 100 miles south of San Francisco). The climate of the southern Santa Cruz County coastal zone is "marine Mediterranean", with mild, wet winters, cool summers, and frequent summer fog along the coast. Mean annual precipitation varies within the region because of the proximity to the coast; typical rainfall amounts average from 35 to 40 inches in the Santa Cruz Mountains and 16 to 22 inches near the Ocean. The mean annual precipitation at Watsonville is about 22 inches.

The Pajaro Valley is an alluvial basin formed by a structural geologic depression and erosional processes which have resulted in its spoon-like shape and in the evolution of the complex slough system on the northern edge of the basin (*Esmaili, 1978*). Watsonville Slough System is composed of a branching network of six seasonally wet sloughs. The Watsonville Slough is the main branch, draining its five arms (Harkins, Hanson, West Branch, Struve and Watsonville Sloughs) that extend up the eroded valleys of the marine terraces. About half of the urbanized areas of Watsonville and the town of Freedom occupy land area in the watersheds of Watsonville, Struve and West Branch

Sloughs. Watsonville is the major city in the area, with a population of approximately 33,000 residents. Taken together with the town of Freedom and other unincorporated areas around Watsonville, the entire population of the area is about 51,400 (*1990 U.S. Census*).

The Watsonville area is characterized by low-lying, rounded hills, composed of geologically young, sedimentary deposits, deposited during the Pleistocene epoch, 1.8 to 5 million years ago (*Bergolar, 1990*). The elevations within the slough watershed range from 10 to 400 feet above mean sea level (MSL). Most areas of the sloughs are found below elevation 20 feet (MSL), yet the head waters of some of the sloughs are as high 80 feet (MSL).

The sloughs themselves are generally shallow, open channels with accompanying broad flat floodplain areas that hold, transport, and drain the precipitation and irrigation runoff for all or parts of the Watsonville, Freedom, and Larkin Valley areas, as well as the Pajaro Valley farmlands along Beach Road.

Water Flow and Circulation

The hydrology of the slough system is complex, involving a variety of hydrologic processes, such as hillslope runoff, pump discharge, flood plain retention, deep groundwater recharge and shallow groundwater return flow. The sloughs occupy broad valleys with low to moderate slopes. Many of the slough bottom lands contain small, shallow man-made channels, which contain water year-round and were created to facilitate drainage of agricultural lands. These channels are usually less than thirty-feet wide with low (two to four-foot) banks. During the winter these channels rapidly exceed their capacity and spill over into the broad floodplains within the slough bottoms. The main flow channels in the slough bottoms do not widen through erosion due to the low gradient and low runoff velocities. High runoff conditions (i.e., storm discharges) do not provide sufficient scouring action to transport deposited sediments and maintain deep well-defined channels within the sloughs. The low-flow channels within the sloughs are maintained sporadically by the landowners and by the Santa Cruz County Public Works Department. This involves periodic dredging of accumulated sediment and clearing of vegetation and debris.

The sloughs can be best described according to two separate drainage networks: (1) the east sloughs drainage network, comprised of Watsonville Slough, Hanson Slough, Struve Slough, and West Branch Slough; and, (2) the west sloughs drainage network, comprised of Harkins Slough, Galligan Slough and the Larkin Valley. A general watershed map is shown in **Figure 5-1**; mapping of key drainage features and structures is provided in **Figure 5-2**.

- **East Sloughs Network**. The east sloughs network generally drains the Watsonville urban areas and the flat lying agricultural fields along Beach Road. The upper portions of the east sloughs network are within the City of Watsonville. Rainfall runoff is collected on the streets of Watsonville and is delivered to the city storm drains, which discharge to the sloughs at numerous locations in the upper portions of Struve, West Branch and Watsonville Sloughs. Struve Slough runs through the middle of Watsonville; and there are several road crossings and urban land use encroachments within its broad bottom. West Branch Slough only has minor amounts of urbanized area and, for the most part, is one of the best preserved sloughs in the system. Moving downstream, but still within the city limits, West Branch and Struve Sloughs begin to widen and become flat broad valleys. In this area there are numerous roadway crossings, many of which are flooded and closed during the winter months when water levels rise in the sloughs. West of Highway 1 the land use around the eastern sloughs network changes the character of the sloughs. Extensive agricultural development has covered most of the old slough wetland system and channels have been created to confine the runoff into trapezoidal ditches bordering the agricultural fields. This portion of the eastern slough network is managed extensively. Periodically, the constructed slough channels are dredged and cleaned to provide increased channel capacity and flood control to reduce overbank flooding into the agricultural fields. There are no pump stations within this section into the slough system. Runoff flows by gravity to the lower section of Watsonville Slough where it is pumped, at Shell Road, to the estuarine portion of Watsonville Slough which flows into the Pajaro River estuary and, ultimately, the ocean.

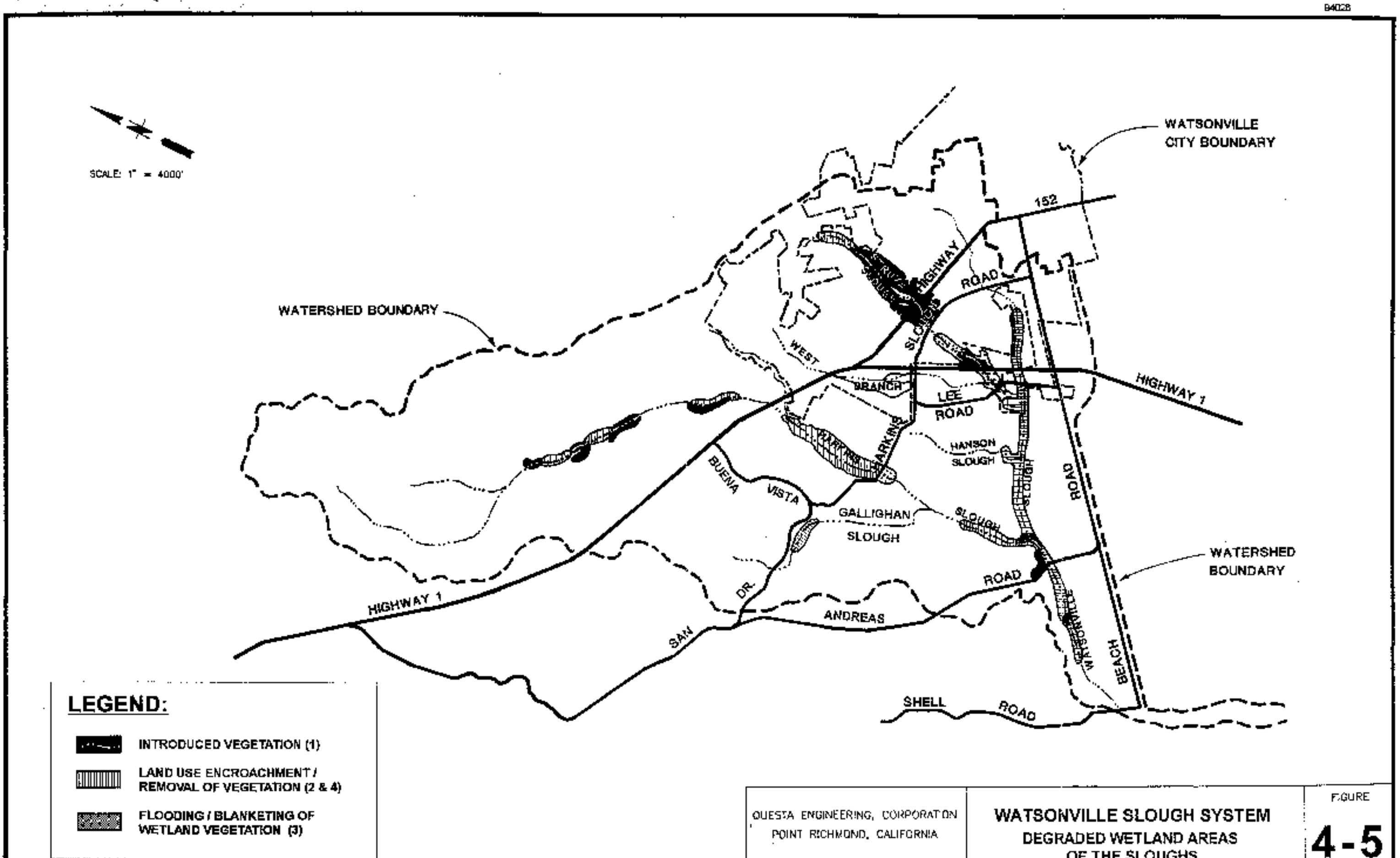
- **West Sloughs Network**. The west sloughs network is dominated by Harkins Slough and the Larkin Valley, which comprises the upper watershed of Harkins Slough. This portion of the system is different from the east section due to the predominance of open space, agricultural and rural residential land uses in the watershed. Little urban runoff is discharged to the west sloughs network. The Harkins Slough begins as a meandering stream channel, draining hillside areas of the Larkin Valley. Here the channel is somewhat incised and only experiences overbank flooding for short durations and during large magnitude runoff events. The channel then passes under State Highway 1 through a box culvert, after which the character of the channel changes. Below Highway 1 Harkins Slough takes on the character of the other slough channels in the east sloughs network, i.e., a small channel within a relatively large broad floodplain in the valley bottom, where streamflow velocity decreases considerably. There are two major channel structures in this part of Harkins Slough: (1) Harkins Slough Road, with a small box culvert; and, (2) the Southern Pacific Railroad tracks, with a 40-foot wide trestle bridge. Downstream of the Harkins Slough Road crossing is the junction with Gallighan Slough. Gallighan Slough originates in the northwestern portion of the watershed and drains primarily hillside agricultural fields, the City and County landfill sites, and scattered rural development. Gallighan Slough flows through a broad, flat riparian forest with small, shallow stream channels occupying the bottom. Downstream of the confluence with Gallighan, Harkins Slough terminates at the junction with Watsonville Slough, where two pump stations lift water from Harkins Slough to the Watsonville Slough channel. The pumps were designed to operate simultaneously. The discharge from these pump stations are 1,600 and 2,200 gallons per minute (gpm), respectively, which equates to 3.5 and 5 cubic feet per second (cfs). The total combined discharge of the pumps is 3,800 gpm (*personal communication, Charlie McNiesh, PVWMA, 2/6/95*). The pumps are used primarily in the growing season to drawdown water levels in the lower portions of Harkins Slough to allow farming on the adjoining fields in the area downstream of the railroad tracks.

- **Shell Road Pump Station**. Downstream of the Harkins Slough - Watsonville Slough confluence, water flows by gravity to the main pump station, located at Shell Road. This County owned/operated facility separates the downstream tidally influenced portion of the Watsonville Slough from the freshwater section. Runoff from the sloughs is pumped into the tidal portion of Watsonville Slough by two large pumps. The rated capacity of these two

FIGURE 5-2 LEGEND

CHANNEL CONDITIONS AND DRAINAGE FEATURES

1. **Shell Road Pump Station** - two pumps draining Watsonville Slough.
2. **Harkins Slough Pump Station** - one pumps lifts water from Harkins Slough to Watsonville Slough.
3. **Junction of Harkins Slough and Southern Pacific Railroad** - a 40 to 50-foot wide trestle bridge.
4. **Southern Pacific Railroad Crossing at Watsonville Slough** - two 5.5-foot corrugated metal pipes (CMP).
5. **Beach Road Ditch Outlet** - 5.5-foot culvert drains into lower Watsonville Slough.
6. **Watsonville Slough at Lee Road** - channelized slough passes through two 5.5-foot CMPs.
7. **Struve Slough at Lee Road** - multiple small culverts underline roadway.
8. **Watsonville Slough at Highway 1** - large, concrete overspan bridge.
9. **Watsonville Slough at Harkins Slough Road** - multiple metal culverts underlie roadway.
10. **Highway 1 at Struve Slough** - large, concrete overspan bridge.
11. **Harkins Slough Road at Struve Slough** - two CMP culverts underlie low roadway.
12. **Harkins Slough Road at West Branch** - multiple CMP culverts.
13. **Harkins Slough Road at Harkins Slough** - approximately 6 x 6 box culvert underlie roadway.
14. **Gallighan Slough at City Dump**.
15. **Buena Vista Drive at Gallighan Slough** - large concrete culverts.
16. **Ramport Road at Harkins Slough** - multiple culverts under road.
17. **Main Street at Watsonville Slough** - box concrete culverts.
18. **Main Street at Struve Slough** - large concrete culverts.
19. **Highway 1 at West Branch** - large box culvert.
20. **Highway 1 at Harkins Slough** - large box culvert.
21. **Buena Vista Drive at Harkins Slough** - multiple culverts.
22. **Upper Harkins Slough** - intermittent CMPs underlying cross streets.
23. **Pennsylvania Drive at Struve Slough** - CMPs under roadway.



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WATSONVILLE SLOUGH SYSTEM
DEGRADED WETLAND AREAS OF THE SLOUGHS

FIGURE 4-5

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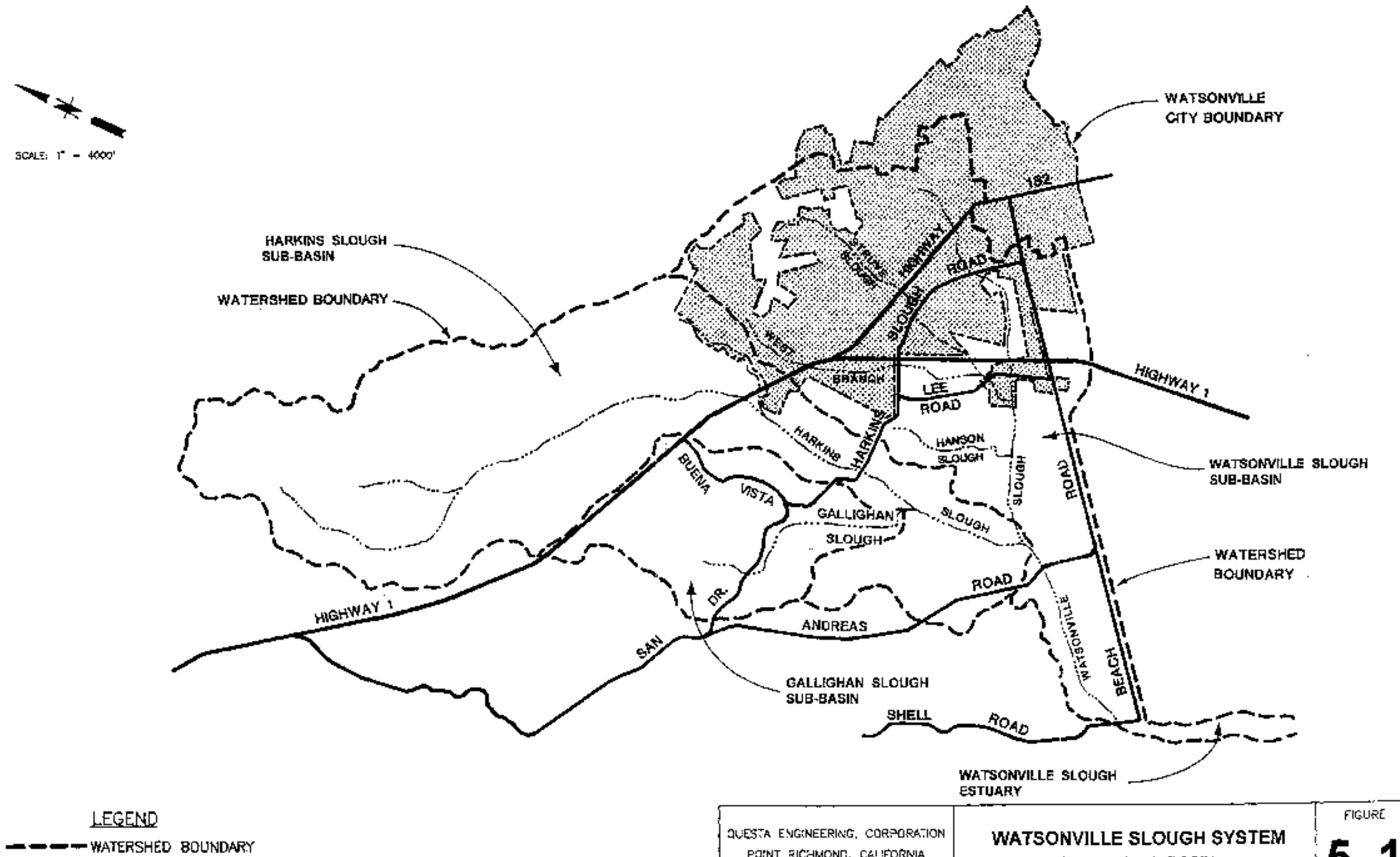

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WATSONVILLE SLOUGH SYSTEM
WATERSHED BASIN
DIVIDED INTO SUB-WATERSHEDS

FIGURE
5-1

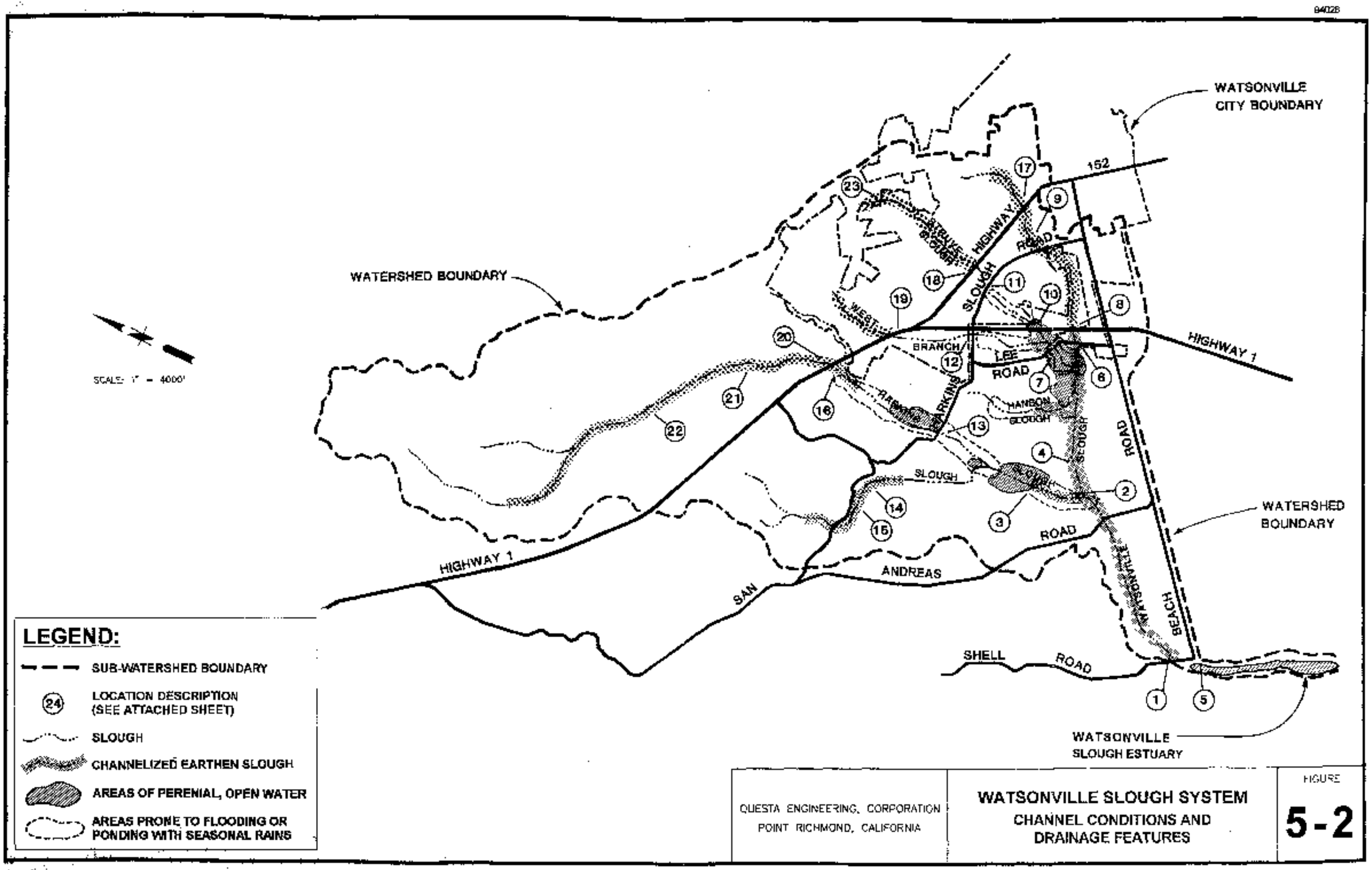


FIGURE 5-2

WATSONVILLE SLOUGH SYSTEM
CHANNEL CONDITIONS AND DRAINAGE FEATURES

pumps are 10,000 gpm (or 22.28 cfs), and 10,750 gpm (or 24 cfs), respectively. These capacities are based on Santa Cruz County measurements taken in 1986 (*Charlie McNiesh, PVWMA, personal communication, 2/6/95*). However, in January 1995 PVWMA installed water meters at the two Shell Road pumps, which indicated pumping rates of 6,600 gpm and 8,500 gpm, respectively. The mode of pump operation depends upon the situation. In the winter months the pumps are set to operate 24 hours a day, to maintain slough water levels below flood stage. The pumps are activated by water level controls (a set of electrodes), which signal to the automatic start-up and shut-off of the pumps. These electrodes are set to prohibit flooding of Shell Road (*personal communication, Terry Reynolds, 2/9/95*).; although, the water in the estuary can at times overtop the Shell Road tidegates and flow "backwards" into the lower slough. Throughout the rest of the year, pump operation is varied according to the levels of high tide and the amount of irrigation runoff into the sloughs. The pump goals are to keep the adjacent farmland dry, while still maintaining as much water as possible in the sloughs (*Terry Reynolds, 1995*).

As a general matter, the County does not maintain good records or set schedules for the operation of the pump stations. Summer pump operation is largely done in response to calls from farmers. Better records would allow a more thorough analysis of the pumping operations and their relationship to water level conditions in the sloughs.

- **Road Crossings**. The sloughs are crossed by numerous roads. These crossings are important because of their flow restricting influence on inundation regimes during the dry season. Within the slough areas there are a wide variety of crossings including full-span trestle bridges, single corrugated metal pipes (CMP) culverts, and multiple-culvert crossings. Because the sloughs are broad and the flow through them is slow, sediment readily accumulates within them. This is very apparent at the culverted road crossings, where many of the culverts are partially or completely full of sediment. According to the County Public Works staff, the observed culvert blockages may also be at least partly attributable to settlement of the roads (and culverts) in the peaty, organic soils in the slough bottoms (*personal communication, Terry Reynolds, 5/4/95*). In the upper portions of the watershed, where gradients are steeper, the culverts and road crossings generally remain clear of sediment and do not normally constrict the flow of runoff. The exception would be during high, intensive storm events, when culvert capacity is exceeded; and then the flooding lasts for a short duration only. During the winter and spring most of the broad low-lying areas of the sloughs are flooded. As a consequence, many of the road crossings within the slough system are inundated throughout the winter and into late spring or early summer. During the summer the constricted flow conditions at these crossings cause water to be retained behind them, and can serve to some extent as low-flow summer dams. These portions of the sloughs then function essentially as seasonal ponds/wetlands throughout much of the summer.

- **Tidal Influences of Watsonville Slough**. The lower section of the Watsonville Slough System (downstream of the Shell Road Pump Station) is tributary to the Pajaro River estuary. This and other tributary sloughs and marshes are remnants of a historically larger, mixed freshwater/estuarine wetland system (see **Figure 4-1, Section 4**). Water levels and flow in the lower slough are dependent upon the channel and beach depositional dynamics of the river mouth, tidal conditions and outflow from the Watsonville Slough System.

The Pajaro River mouth is typical of a California coastal stream estuary. The system experiences dynamic changes from season to season. In the winter, when stream flows are high, the river mouth is typically open to full tidal inundation as river water discharges to the ocean. The force of the stream flow keeps the mouth open against the forces of beach sand littoral sedimentation. As the spring progresses, flows in the river are reduced and it becomes increasingly difficult for the river to maintain a constant opening and connection to the ocean. The River may break through during moderate to high rainfall events; but, soon thereafter, beach sand will be deposited and the mouth will be closed as flows decline. By late spring/early summer the flows in the river drop significantly and the river mouth is closed to tidal influences until stream flows increase enough in the fall to break through the beach sand barrier again. Throughout the summer, the impounded flows in the low Pajaro River cause the water level in the estuary to rise. During this period, the water quality of the estuary undergoes a basic change. Salinity declines due to the decreased tidal inflow and the impoundment of freshwater flows. Wind helps to mix the freshwater and remanent salt water together forming a brackish lagoon. This is the natural cycle of small coastal estuaries such as this.

However, often because of discharges (e.g., agricultural return flow and dewatering of the slough channels) within the river and slough watershed, lagoon levels continue to rise throughout the summer and have the potential to flood the neighboring areas. Flooding also inundates the salt marsh areas of the slough with predominately freshwater. This can have a detrimental effect on the salt marsh plant communities, because of their inability to tolerate long periods of freshwater inundation. When the flooding is severe Santa Cruz County will breach the sandbar at the mouth to drain the lagoon to ease potential flooding problems. But, this also can have other adverse environmental consequences. This is a development activity that requires a coastal development permit. The summer breaching allows tidal inundation for short periods of time and creates a stratified water column in the lagoon and slough system. The stratification occurs because the more dense sea water will flow to the bottom of the estuary, while the inflowing freshwater remains above the salt water. These stratified conditions cause problems for fish and other aquatic organisms that do not have high tolerances to salinity and temperature fluctuations. To address such impacts interim emergency breaching criteria were established in April 1992 and are embodied in the May 1993 Pajaro River Lagoon Management Plan. Santa Cruz County now has contracted with a consultant to develop a permanent, environmentally sensitive program, the Pajaro River Corridor Management and Restoration Plan, due for completion in 1997.

5.2 GROUNDWATER RESOURCES

Water-Bearing Formations

The Watsonville Slough System lies above the boundaries of the Pajaro Valley Groundwater Basin.

Water supply in the Pajaro Valley comes from three water-bearing units: (1) the Quaternary alluvium; (2) the upper and lower Aromas Red Sands; and, (3) the basal Purisima Formation. A generalized schematic cross-section of these formations and their relationship to the Watsonville Sloughs system is shown in **Figure 5-3**. The main production of groundwater in the Pajaro Valley is pumped from the stratigraphic sections of the Aromas Red Sands. The Aromas Red Sands and the Purisima Formations are overlain by layers of blue clay which act as a confining layer, inhibiting the free vertical movement of the groundwater from the overlying Quaternary alluvium. Water quality differs significantly between the deeper, confined Aromas Sands and Purisima Formation and the shallow semi-perched groundwater in the upper alluvium (*Brown, et al, 1976*); the deep groundwater is of better quality and is the preferred source for local water supply uses.

- **Quaternary Alluvium - to 100 feet**. The Quaternary Alluvium has three distinct sub-units: terrace deposits, alluvium, and dune sand units. The Alluvium unit ranges from approximately 50 to 300 feet in thickness (*EIP, 1993*); beneath the Watsonville Slough System area, it is about 100-feet thick. The terrace deposits consist of unconsolidated basal gravel, sand, silt, and clay. The alluvium deposits consist of inter-layered beds of unconsolidated finer grained sands, gravel, and clay deposited by the Pajaro River and coastal streams to the north. A 50-foot thick basal gravel layer underlies the blue clay marker bed and is hydraulically connected to the Aromas Red Sands. The blue clay is a continuous unit beginning four-miles west of the Pajaro Gap and extending to the coast (*EIP, 1993*). This clay layer, where it occurs, precludes direct precipitation recharge of the underlying Aromas Reds Sands aquifer; this creates the perched groundwater which supports the extensive wetland conditions within the slough bottoms.

- **The Aromas Red Sands - 100 to 800 feet**. Underlying the alluvium and blue clay layer are the Aromas Red Sands. These sands consist of fluvial (i.e., river) and eolian (i.e., wind) deposits which hold discontinuous confining layers of interbedded clay, gravel, and silty clay (*Luhdorff and Scalmanini, 1987*). The confining clays dominate in the fluvial deposits of the Aromas Formation where the clay layers thicken westward (*PVWMA, 1993*). This primary water-bearing unit ranges in thickness from 100 to 800 feet and outcrops in a discontinuous ring around the periphery of the Pajaro Valley Groundwater Basin and within the Watsonville Slough System watershed. The Aromas Formation outcrops can be found in the northwestern and north portions of the Gallighan and Harkins Slough watersheds. Where these outcrops of the Aromas Formation occur, they potentially create a direct avenue for percolating rainfall (and other applied water) to recharge the deep aquifer, bypassing the slough system.

- **The Purisima Formation - below 800 to 900 feet**. The Purisima Formation underlies the Aromas Red Sands and consists of three main units of marine deposits. These units are comprised of interbedded sands, silts, clays, and shale. This formation has been tectonically warped into a broad shallow spoon-shaped depression that opens southward, toward Monterey Bay (*Esmaili, 1978*). The upper section of the formation is a very fine to fine sand with clay and silt interbeds. The middle section is a fine to medium sand with clay, silt, and gravel interbeds. The lower section consists of sand with clay and shale interbeds. A 150-foot thick shale marker bed, lying approximately 600-feet below the top of the lower unit, exists continuously throughout the valley (*PVWMA, 1993*). The Purisma sediments lying beneath the center of the Pajaro Valley are finer-grained due to the greater distance from the source areas (*Green, et al, 1979*). The grain size within the formation tends to increase near the source areas and outer fringes of the basin. Beneath the central part of the valley the Purisma Formation is 1,000 to 2,000-feet thick and generally thins to the southeast.

The deep aquifer of the Purisma Formation in the Pajaro Valley vicinity is considered restricted regarding its capacity to yield fresh, clean water. These restrictions are caused by: (1) lithologic variations, i.e., thinning or fining toward the basinal/depositional axis; (2) discontinuity of units; and, (3) the location and distance away from the recharge areas (*Luhdorff and Scalmanini, 1987*). The Purisma Formation's geologic extent, slope, and shape influence overlying bedforms and drainage patterns at the surface and restrict vertical movement of groundwater below the surface (*Esmaili, 1978*).

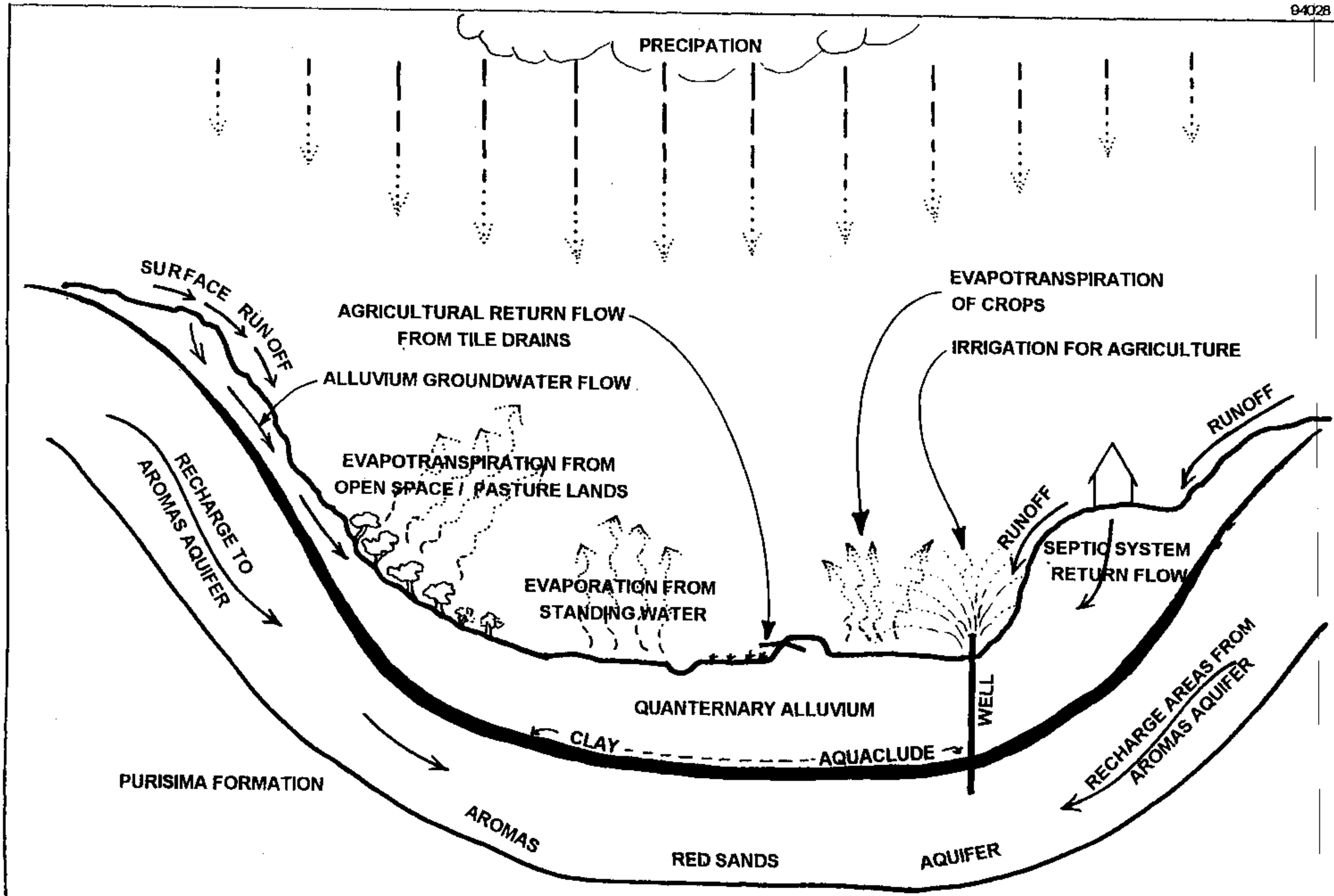
Wells in the Water-Bearing Units

The main production of groundwater in the Pajaro Valley is from the Aromas Sands (*Luhdorff and Scalmanini, 1987*). The largest production wells generally extend to about 800 feet below the ground surface, i.e., to the top of the underlying Purisma Formation (*Luhdorff and Scalmanini, 1983*). Existing production wells in the deeper sections of the Purisma Formation are tapped in the Soquel area and the Salinas Valley (*Luhdorff and Scalmanini, 1987*). Wells have not tapped the Purisima Formation in the Pajaro Valley because of the assumed difficulties involved with this deep aquifer and the fact that the Aromas Sands are known to produce the highest yield.

Groundwater Recharge

The groundwater of the deep aquifers in the Pajaro Valley area is recharged mainly by the direct percolation of precipitation through the soils, accounting for 90 percent of the total recharge to the basin (*Johnson, 1982*). The other 10 percent of recharge is attributed to seepage from the headwater areas of Corralitos Creek, infiltration from the Pajaro River and other tributary streams, along with the continuous underflow between adjacent areas (*Brown et al, 1976*). The primary groundwater recharge areas lie in the regions of accessible unconsolidated sands, sandstones, gravel, or silts of high permeability on the outskirts of the Pajaro Valley basin. The areas of the highest recharge potential to the Aromas Sands are located in the coastal dune facies, north and south of the Pajaro River and along Corralitos Creek above the town of Freedom (*EIP, 1993*). These recharge zones correspond with areas of eolian and alluvial sediment deposition, where there is no confining clay layer to restrict downward movement of rainfall percolation. **Figure 5-4** shows the groundwater recharge areas of the Watsonville Slough System watershed.

In the Watsonville Slough System area, percolation of surface water into the underlying aquifer is affected by the overlying system soil. In general, the presence of near-surface confining and semi-confining clay layers in the sloughs and surrounding floodplain impede the downward flow of water into the deeper aquifers. Consequently, the sloughs do not account for significant recharge to the deep aquifers of the Aromas Sands.



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WATSONVILLE SLOUGH SYSTEM
GEOLOGIC / WATER BUDGET SCHEMATIC

FIGURE **5 - 3**

The spoon-like shape of the basin allows for groundwater to flow away from recharge areas and toward the central northeast-southwest axis of the Pajaro Valley and westward, toward Monterey Bay. The Aromas sand is the major vehicle for groundwater recharge where groundwater flow is toward the valley floor. The permeability diminishes rapidly landward due to the contrast of coastal eolian deposits and the inland fluvial fine-grained deposits (*Esmaili, 1978*).

Groundwater Flow into the Sloughs

Shallow groundwater flow from the Quaternary alluvium drains into the slough bottoms. This groundwater flow is derived from rainfall and irrigation drainage into the soils and subsequent migration downslope into the sloughs. Shallow groundwater in storage is depleted at the end of the summer and gradually builds throughout the winter rainy season, with discharge into the sloughs continuing through the spring and summer months.

5.3 EROSION AND SEDIMENTATION

During runoff events soils in the slough watershed are constantly subject to erosional forces. Soil erosion is a complex process affected by numerous variables, including soil type, soil texture, rainfall intensity, slope, slope length, water velocity, vegetative cover, and antecedent soil moisture. The Watsonville Slough System has a wide variety of soil conditions and land uses which are affected by differential amounts of erosion. Human activities such as agriculture and construction can greatly increase erosion rates. There is clear visual evidence of soil erosion in the upland portions of the watershed which ultimately results in downstream sedimentation in the slough channels. Where these sediments are not removed by dredging or scouring (e.g., by flood flows), the sediment accretion can cause perennial wetlands to evolve further toward seasonal wetlands.

A portion of the hydrologic study involved a review of existing soil conditions and the application of the Universal Soil Loss Equation (USLE) to develop rough estimates of erosion potential from different areas of the watershed.

Soil Conditions

The surface soils within the Watsonville Slough System watershed have been classified and grouped by hydrologic soil group (see **Figure 5-5**) in accordance with published maps contained in the Soil Survey of Santa Cruz County. The hydrologic soil groups were determined through soil identification charts of the Soil Conservation Service (SCS) National Engineering Handbook, 1986. Soils of Hydrologic Groups B, C and D occur in the watershed; there are no Group A soils in the project area.

- **Hydrologic Soil Group B**. Group B soils have moderate infiltration rates and consist chiefly of moderately deep to deep, moderately well to well drained, moderately fine to moderately coarse textured soils. The western and northwestern portions of the watershed area are dominated by this soil group, including the sub-watersheds of Gallighan Slough and the upper regions of Harkins Slough. The hills surrounding Gallighan Slough and bordering lower Watsonville Slough consist primarily of Baywood loamy sands and Elder sandy loams. The Group B soils in the upper reaches of Harkins Slough and encompassing Larkin Valley Road, consist of mainly Elkhorn sandy loam, Pfeiffer gravelly sandy loam, and Elkhorn-Pfieffer complexes. A small sector in the southeastern corner of the Watsonville Slough sub-watershed is mapped as Conejo loam.

The Baywood loamy sands and Elder sandy loams are very deep, excessively well drained soils and range in slopes of 0 to 50%. The Baywood sands formed in eolian deposits. Surface runoff in this soil range from moderate to rapid, and the hazard of erosion varies from moderate to high, depending upon the slope of the land. Areas of steep slopes within the Baywood sands are subject to extensive rill and gully erosion. The Elder loam formed in mixed alluvium. Surface runoff on the Elder loam is determined as slow to medium with a hazard of erosion of slight to moderate. The Baywood and Elder soils were used extensively for agriculture, the main crops being strawberries and flowers (both field and greenhouse). Brussel sprouts and bushberries are of secondary importance in terms of acreage and value. A few areas are used as rangeland or are being developed as residential sites.

The Elkhorn sandy loam and Pfeiffer gravelly sandy loam are very deep well drained soils on old alluvial fans and marine terraces. These soils range in slopes of 15 to 50 percent. Surface runoff on the Elkhorn loam ranges from medium to rapid with the hazard of erosion being high. The Pfieffer loam formed in material weathered from granitic rock, sandstone, and marine sediments. Surface runoff on the Pfeiffer gravelly loam is rapid and the hazard of erosion is high. The steep slopes of the Larkin Valley draining into Harkins Slough result in the high rates of erosion for these loams. The majority of Group B loams in the upper Harkins Slough are used as rangeland with a few areas used for crops, such as apples, bushberries, strawberries, and brussel sprouts.

The Conejo loam is a very deep well drained soil on alluvial fans and plains. These soils have slopes of 0 to 2 percent. Surface runoff is slow and the hazard of erosion is slight. Irrigated row crops and urban land uses occur on these soils.

- **Hydrologic Soil Group C**. Group C soils have low infiltration rates when thoroughly wetland and consist chiefly of soils with a layer that impedes downward water movement. Group C encompasses the southern region of the watershed and interfingers upslope through Harkins Slough into the mid-section of the watershed, involving the upper regions of Harkins and Watsonville Slough sub-watersheds. Group C refers to fine textured soils ranging from loams to clays. Group C includes Clear Lake clay and the Pinto loam. The Clear Lake clay lines the Watsonville and Harkins Slough channels and floodplains, and dominates the southern stretch of the Watsonville sub-watershed. The Pinto loam occurs in various locations upslope of Hanson, West Branch, and Struve Sloughs.

The Clear Lake clay is a very deep moderately wet soil that occurs in alluvial basins. Slopes range from 0 to 2 percent. These soils are artificially drained by underlying tile drains, diversion ditches, and pumps in order to avoid extensive saturation and flooding. The

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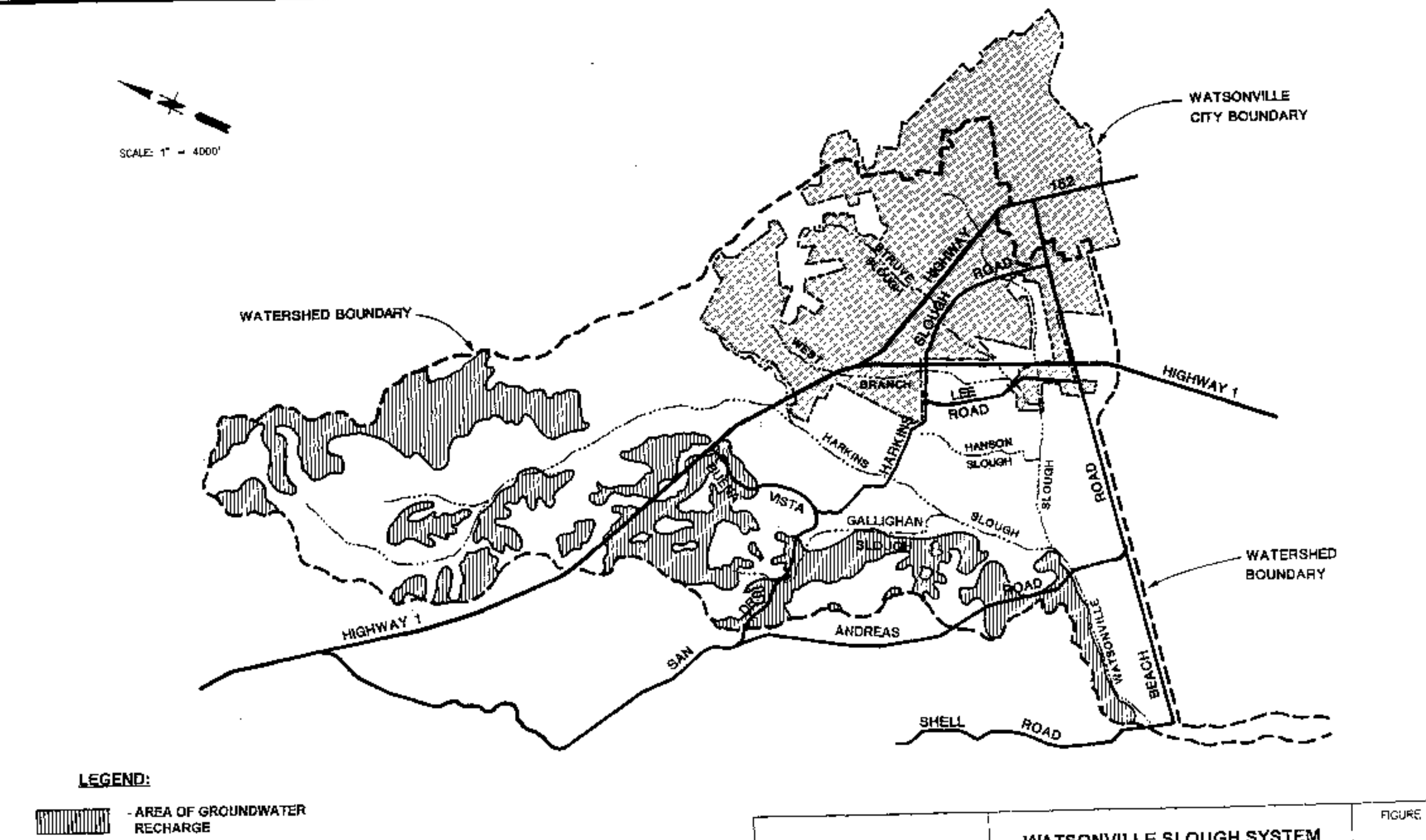

SOURCE: SANTA CRUZ COUNTY PLANNING DEPT. OCTOBER 1994

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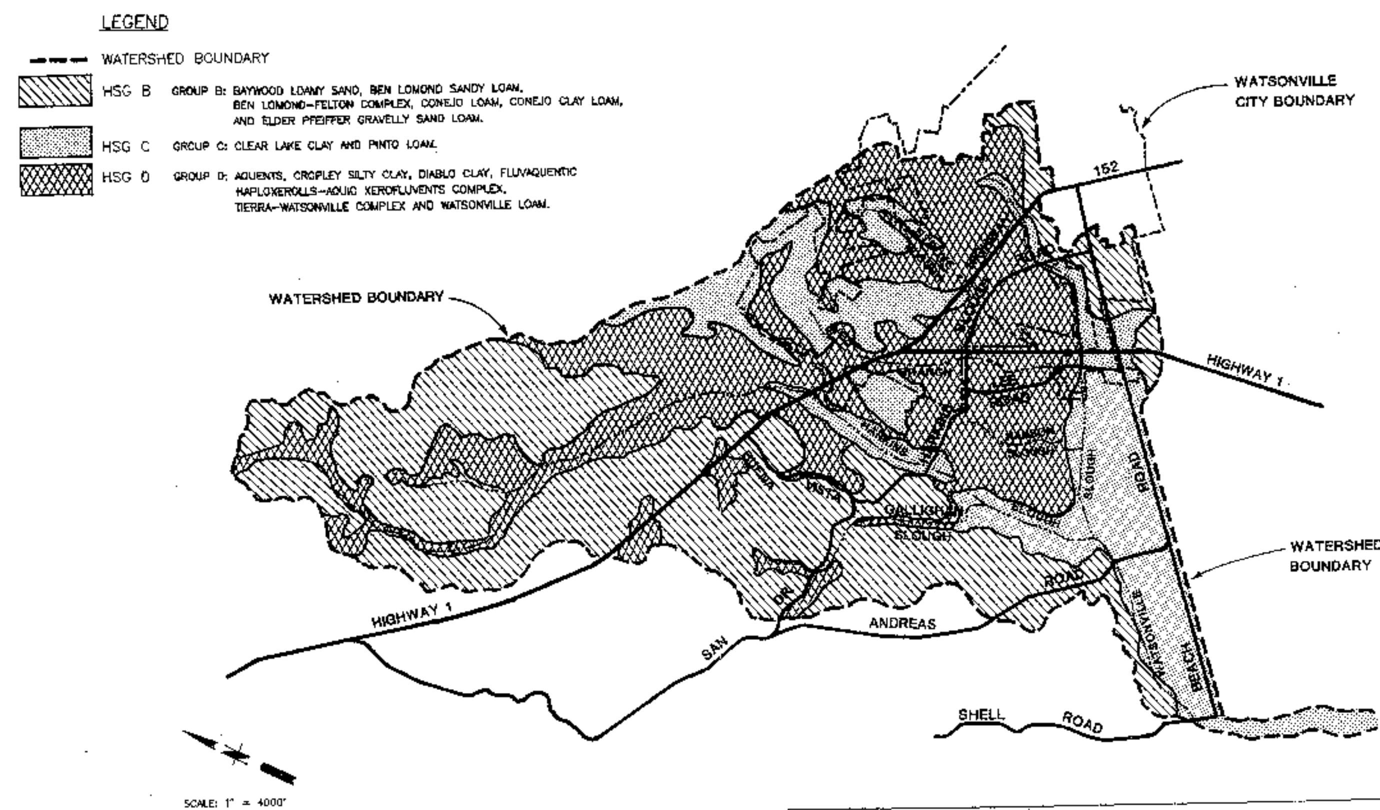
WATSONVILLE SLOUGH SYSTEM
AREAS OF GROUNDWATER RECHARGE

FIGURE 5-4



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WATSONVILLE SLOUGH SYSTEM
HYDROLOGIC SOIL GROUPS (HSG)

FIGURE
5-5

permeability of the clay is very slow. In the low-lying area, the water table is usually at a depth of 36 to 72 inches below the ground surface. Surface runoff is very slow and the hazard of erosion is slight. The Clear Lake clay is used mainly for irrigated row crops, i.e. brussel sprouts, broccoli, and cauliflower.

The Pinto loam is a very deep, moderately well drained soil found on coastal terraces and old alluvial fans. Slopes range from 0 to 15 percent. Within the Pinto soils, water tends to be seasonally perched above the compacted subsoils. Surface runoff is slow and the hazard of erosion is slight. These soils are cultivated with apples, bushberries, and row crops and surround the Watsonville Airport and neighboring urban regions.

- **Hydrologic Soil Group D**. Group D soils have high runoff potential and low infiltration rates when thoroughly wet. They consist mainly of clay soils with high swelling potential. Group D occupies the areas of Hanson, West Branch, and Struve Sloughs and continues northward, lining Galligan Slough and spanning Larkin Valley along Harkins Slough. Group D includes the Cropley silty clays, Diablo clays, and Aquents that extend throughout the southern regions of the watershed, lining Hanson Slough, West Branch Slough, Struve Slough, portions of central Harkins Slough and upper Watsonville Slough, and their associated ridges. Galligan Slough and the upper portion of Harkins Slough are lined with organic peat soils. The upper Watsonville Slough sub-watershed and the central and upper regions of the Harkins Slough sub-watershed contain soils of the Watsonville loam and Tierra-Watsonville complex.

The Cropley silty clay is a very deep well drained soil on alluvial fans and benches. Slopes range from 2 to 9 percent. Permeability of the soil is slow and surface runoff is slow or medium with a slight hazard of erosion.

The Diablo clay is a well drained soil found on hills and formed in material weathered from sandstone and shale. Slopes range from 9 to 30 percent. Permeability of the soil is dependent upon the existing moisture content within the soil, i.e., the wetter the soil, the slower the permeability rate. Surface runoff is medium to rapid and the hazard of erosion is moderate to high.

The organic peat soils of Harkins and Galligan Sloughs occur in the open channels and floodplains. These soil complexes consist of sandy clays and peats that are frequently inundated by runoff water. Drainage is very poor and the runoff is very slow. There is no hazard of erosion except when runoff is rapid. Depth to the water table ranges from 10 inches in the winter months to 40 inches during the dry summer months (Santa Cruz County Soil Survey). These soils have historically been mined for peat resources - most recently (in the early 1980s) in the lower reach of Harkins Slough, between Harkins Slough Road and the railroad trestle.

The Tierra-Watsonville complex and Watsonville loam are rather poorly drained soils located on marine terraces. Slopes range from 2 to 50 percent. Permeability of the soils is very slow and the available water capacities range from four to five inches. Water is seasonally perched above the clay layers within these soils. The runoff ranges from slight to rapid. The hazard of erosion is dependent upon the slope and cover type of the land and ranges from moderate to high. A few gullies have formed in the steep areas of these clays.

USLE Soil Erosion Estimates

Estimates made according to the USLE should be taken as an indication of the relative amounts of soil loss possible within given areas of the sloughs watershed. Predicting actual sediment loss in a precise manner is very difficult and requires extensive long-term monitoring data; erosion can vary radically from year to year, in response to rainfall frequency, cultivation practices, and many other factors.

The USLE is an empirical model developed by the U.S. Department of Agriculture to estimate sheet and rill erosion from agricultural lands. It is an equation that calculates an erosion rate. The equation consists of five variables based largely upon soil conditions.

The general form of the equation is:

$$A = R \times K \times LS \times C \times P$$

where:

A = soil loss rate, tons/acre/yr
R = rainfall erosion index, 100 ft-tons/acre-inches/hour
K = soil erodibility factor, tons/acre per unit of R
LS = slope length and steepness factor, dimensionless
C = vegetative cover factor, dimensionless
P = erosion control practice factor, dimensionless (*Goldman et al, 1986*).

Soil conditions are a principal factor in determining the erosion potential for a given area or site. As described in the preceding paragraphs, the Watsonville Slough System has areas of varying soil characteristics with distinct differences in soil erodibility. For the purposes of this USLE analysis, the Watsonville Slough System was divided into sub-watersheds related to the individual sloughs. Each slough watershed was divided into categories according to similarities in land use, soil erodibility, and slope length and steepness of the land. A soil loss rate was calculated for every category for each individual slough watershed. An annual soil loss amount was then estimated by multiplying the erosion rate by the corresponding area for each specific category. Adding the annual soil loss quantities for each category then resulted in an estimated soil loss for the sub-watershed; the tables showing the calculations for each sub-watershed are included in **Appendix A.**

The R, K, and C variables within the USLE were obtained by tables prepared by the U.S. Department of Agriculture. The Highly Erodible Land (HEL) Classes List for Santa Cruz County determines an R value of 50 for the Watsonville study region. The HEL and the Soil Survey of Santa Cruz County correlate soil names with related erodibility, or "K", factors (see **Figure 5-5**). The Watsonville Slough sub-watersheds contain soils of erodibility values of 0.15, 0.17, 0.24, 0.28, and 0.32. The vegetative cover factor (C) is dependent upon the land use within the sloughs, agricultural or open space. The HEL indicates the C value of agricultural land within the slough system to be 0.1, areas of 90 percent cover. The C value for roadside and ditch conditions involving exposed soils within the agricultural fields was estimated to be 1. The C value for open space/native vegetation corresponds to a numerical value of 0.01.

The surface condition of the land determines the P value. Agricultural land use **has a P** value of 0.9, based on contour plowing, parallel to topographic contours. Regions of native vegetation have P values of 1, indicating undisturbed open space.

The transport of soil particles over an area is strongly influenced by the slope gradient and slope length of the land. Slope gradient and slope length are used to determine an LS value for the desired region. Topographic maps were used for the calculation of percent slopes and slope lengths within the set categories of the sloughs. **Table A-1** (provided in **Appendix A**) relates the slope gradient and slope length to predict an LS factor. LS values are small, less than 1.00, on slopes less than 5 percent with slope lengths less than 300 feet. On steep slopes, soil movement increases dramatically. For example, portions of the strawberry fields of Galligham Slough are located on hills of 18-percent slope, with slope lengths of 1,000 feet; this results in an LS value of 9.56.

Using the USDA constant of R and C values while categorizing the sloughs on the basis of land use, erodibility factors, and LS values yields a detailed estimation of potential soil loss for the different sub-watersheds of the sloughs. The results of this USLE analysis are summarized in **Table 5-1**, showing the estimated erosion rates on the basis of: (a) tons/acre/year; and, (b) total tons/year for each of the sub-watershed areas. The percentage contribution from each area is also indicated. It is apparent from this generalized analysis that agricultural areas represent a much greater source of potential erosion to the Slough System than do the urban areas.

For comparison purposes, typical soil loss rates for the kinds of land use conditions in the Watsonville Slough System watershed are as follows:

- open space/grasslands - < 1 ton/acre/year
- graded areas - 3 to 30 tons/acre/year
- row crops, flat terrain - < 3 ton/acre/year
- row crops, hillside areas - 3 to 30 tons/acre/year

However, according to Rich Casale, with the NRCS, rills don't start forming until the loss rate is 15 tons/acre/year; and rills as well as large gulleys are evident in some places in the watershed. This suggests a loss rate of much more than 15 tons/acre/year, at least in these localized areas. This topsoil loss rate equates to about an inch in every 25 years, this is excessive since it is much greater than the rate of topsoil formation.

5.4 WATER MANAGEMENT PRACTICES AND INTERESTS

Water management activities in the Watsonville Slough System involves a diverse and sometimes competing group of interests and practices. Following is an overview of the key management

Table 5-1: Erosion Estimates for the Sub-Watersheds by USLE

Slough	Sub-Watershed Area (acres)	Erosion Estimate (Tons/acre)	Sediment Loss (Tons/year)	Percent of Total Annual Sediment Loss
Gallighan	1375	2.7	3731.2	32.3%
Harkins	5300	1.2	6542.7	56.6%
Hanson	318	0.7	230.3	2.0%
West Branch	552	0.3	181.7	1.6%
Struve	917	0.1	101.4	0.9%
Watsonville	2152	0.4	765.9	6.6%

Total Annual Sediment Loss for the Watsonville Slough System 11553.2

elements that need to be considered in devising a long-term management plan for the watershed.

Agriculture

Agriculture is the predominant industry in the project area and is the main water user. Water management issues of concern to agriculture include: (a) irrigation water supply; (b) drainage; (c) flood control; and, (d) soil erosion.

- **Irrigation Water Supply**. Irrigation water supply in the Watsonville Slough System area comes almost exclusively from deep wells in the Aromas Sands aquifer. As such, it is not affected by water quality conditions or flows in the sloughs; however, the Aromas Sands are recharged in part by deep percolation of rainfall which occurs in portions of the Gallighan Slough and Harkins Slough watersheds. The current groundwater pumping from the Aromas Sands does not affect the sloughs; but plans currently under consideration by the PVWMA (see discussion below) to divert runoff for groundwater recharge could create a new linkage between irrigation uses and overall slough hydrology and water quality.

- **Drainage**. Agricultural lands in low-lying areas of the Pajaro Valley (e.g., along Beach Road) and the Watsonville Slough System require subdrains to control the water table and provide subsurface drainage. Subdrains have been installed throughout the fields in this area which discharge directly to roadside ditches and to the sloughs. This drainage practice is critical to the agricultural lands; but it also represents a significant potential source of pollutant discharge to the sloughs during the irrigation season. In the winter, when only minor irrigation occurs, these subdrains discharge primarily rising groundwater due to rainfall percolation.

- **Flood Control**. Some low-lying agricultural lands adjacent to the sloughs are potentially subject to flooding during winter runoff. Measures taken to protect the farm fields from flooding include periodic cleaning of man-made channels (both sediment and vegetation) and operation of the Harkins Slough and Shell Road Pump Stations to maintain acceptable water levels and facilitate outflow from the sloughs.

- **Soil Erosion**. Soil erosion primarily affects hillside agricultural operations, where the soil erodibility hazard is high. Erosion from these fields tends to accumulate in roadside ditches and downstream channels, causing drainage maintenance problems and contributing to the overall sediment and pollutant loading to the sloughs. In addition to on-site control of erosion, farmers are required by the County Public Works Department to clean and recover sediment which accumulates in the roadside areas bordering the fields. If this is not done, the farmers are levied the costs by the County to do the cleaning, but no penalties are assessed.

- **Peat Harvesting**. In 1982 Anderson Peat Company (the Old Fort Industries) received a coastal development permit from the California Coastal Commission to mine peat from up to 300 acres in portions of the Harkins, Hansons, Gallighan, West Branch Struve, and Watsonville Sloughs in phases over an 8 to 16-year period. The mining involves draining the

Slough waters and results in more open water areas after harvesting. Mined areas are to be restored and deeded to the California Department of Fish and Game.

County Roads and Flood Control

Santa Cruz County is responsible for maintenance of roads and drainage/flood control facilities in the unincorporated portion of the Watsonville Slough System watershed. This is carried out through two separate maintenance districts - Santa Cruz County Flood Control District - Zone 7 and the Pajaro Storm Drainage Maintenance District. The major drainage responsibility lie with Zone 7, a special district formed to manage the existing pump stations and other facilities. In this regard, their primary water management activities are: (a) pump station operations; (b) channel maintenance; and, (c) road crossings.

- **Pump Stations**. Zone 7 operates and maintains the main pump station at Shell Road, as well as the Harkins Slough pump station. The pump stations are operated continuously in the winter to prevent flooding of low-lying roads and adjacent lands. During the dry season pumps are operated on an as-needed basis to assure positive drainage from the farm lands, while maintaining permanent water in the sloughs.

- **Channel Maintenance**. A major activity and concern of the County is the sedimentation of drainage channels and road culverts in the sloughs. Dredging and removal of accumulated sediment is routinely required to keep the channels open. The County estimates that approximately 500 cubic yards of sediment are dredged about every three years. This equates to an annual sediment removal rate of about 200 tons/year. The majority of the maintenance activity takes place in the lower portions of Harkins and Watsonville Slough, downstream of Highway 1. In many locations, maintenance cannot keep pace with the rate of sediment deposition; and culvert replacement or enlargement has been required. New culverts will temporarily fix the problem; but, continued sedimentation (combined with road subsidence) will eventually obstruct the flow through new culverts.

- **Road Crossings**. Road crossings in the slough bottoms are routinely closed during the winter runoff season when the flows overtop the roads. This occurs due to the nature of the road construction (essentially at grade through the slough bottoms) and the limited or constricted flow capacity of the road culverts. These seasonal road closures occur well upstream of Shell Road and are not affected by the pump station operations and water level controls at the mouth of the Watsonville Slough. Operation of the Harkins Slough pump station, on the other hand, can affect water levels at the Harkins Slough Road crossing. Zone 7 has a 20-year goal to replace/expand many of the inadequate road culverts that contribute to the need for extended road closures; but, specific projects and implementation details have not been developed as yet.

City of Watsonville

The City of Watsonville lies in the eastern portion of the Watsonville Slough System watershed and has limited involvement in the management of water resources in the sloughs. The potential water issues of concern are: (a) storm drainage/flooding; (b) urban runoff pollutant controls; and, (c) wastewater treatment facilities.

- **Storm Drainage/Flooding**. Presently there are no major flood hazard areas within the City caused by the slough system. The City maintains a network of storm drains, most of which discharge (via pump stations) to the Pajaro River and some of which discharge by gravity to the Watsonville Slough System. Flooding is potentially an issue for future development in portions of the City which lie in low-lying, flood-prone areas adjacent to the sloughs, or which may be affected by the periodic closure of traffic routes through the sloughs. Flood protection, drainage and traffic circulation issues for such development would be a site specific consideration during project review.

- **Urban Runoff Controls**. Urban runoff from the City is a source of non-point pollution to the sloughs, for which the City and individual properties (e.g., industrial sites) have current and future management responsibilities. A variety of control measures, such as industrial discharge requirements, sewer line maintenance, public education, street sweeping, storm drain signage and maintenance, and other maintenance type procedures are currently in place. The need for urban runoff controls may be increased as part of the long-term water quality management program for the sloughs. Also, as a land use agency, the City has control of urban development, wetland protection and buffer protection, all of which can have significant impacts on water resources (see also discussion in **Section 4.7**)

- **Wastewater Treatment Facilities**. The City collects all wastewater in its jurisdiction and operates an advanced primary treatment plant with discharge to Monterey Bay at the 19.5 meter depth contour. This facility currently has no water management significance to the Watsonville Slough System; however, consideration may be given to upgrading the system to an advanced wastewater treatment (AWT) facility, in which case reclaimed wastewater would potentially be available for irrigation use, groundwater recharge, or possibly stream discharge (e.g., for flow augmentation) into the Watsonville Slough System. Any of these potential reclamation uses could affect the hydrology, water quality and overall water resources management in the sloughs.

Pajaro Valley Water Management Agency (PVWMA)

The PVWMA's interest in the Watsonville Slough System, stems from a possible local groundwater recharge project that is currently under study. This project is in connection with their overall efforts to counter groundwater overdraft and sea water intrusion in the Pajaro Valley Groundwater Basin. The project would involve diversion of winter flows from Harkins Slough for direct recharge of the Aromas Sands aquifer via percolation ponds or wells in the hills west of San Andreas Road. The diversion would only intercept winter flows which otherwise discharge through the sloughs into the ocean. The potential water resources management implications for the Watsonville Slough System have not been fully evaluated; but, clearly such a streamflow diversion project would have the potential to affect the winter flow regime for the sloughs by removing runoff and reducing the winter time flushing action in the lower portions of Watsonville Slough and Pajaro River Estuary. This could further degrade water quality conditions by depriving the sloughs of existing dilution water. However, it may be possible to structure a diversion and recharge project that would also return a portion of the flows to the sloughs during the dry season, i.e., as flow augmentation for improved circulation and water quality conditions. This could be a significant benefit to the sloughs.

Mosquito Abatement

The Santa Cruz Mosquito Abatement and Vector Control District (District) has an active program to control the mosquito population in the sloughs. The District uses three types of mosquito larvacides; a lightweight oil, BTI and methoprene, which can be applied by air or with ground equipment. The oil, which contains surfactants, forms a very thin film on the water surface and essentially suffocates both the larval and pupal stages of the mosquito. The oil also impacts other air breathing aquatic insects, such as backswimmers, water boatman and some beetles. The oil tends to dissipate within three to four days, depending on climatic conditions.

BTI (*Bacillus thuringlensis israelensis*) is a naturally occurring bacterial pathogen of mosquitos. It is most effective against the first three of the four larval instars and is not effective against the non-feeding pupal stage. BTI has minimal impact on non-target organisms and is approved by the U.S. Fish and Wildlife Service for use in sensitive habitats.

Methoprene is an insect growth regulator which prevents the mosquito from developing from the pupal to the adult stage. It is most effective against third and fourth instar larvae and will not affect the pupal stage. Extensive research has demonstrated that methoprene has very little impact on non-target organisms, and the U.S. Fish and Wildlife Services has given the District permission to use methoprene in habitats where the endangered Santa Cruz long-toed salamander is present.

Generally, the District's annual control program within the Watsonville Slough System consists of one or two aerial applications of BTI, methoprene or, if pupae are present, oil. Aerial applications are usually required in late winter or spring when there is extensive breeding of *Aedes washinoi*, a vicious, day-biting mosquito. Mosquitos can be found almost year-round in the sloughs, and the District uses ground equipment, such as backpack sprayers, for point applications of larvicides. Control efforts focus on mosquito habitats that are adjacent to urban areas.

From a water management standpoint, mosquito abatement is facilitated by having convenient access to ponded water areas, and minimizing the occurrence of shallow, standing water conditions. Deep, open and free flowing water allows predators to aid in control of mosquito breeding. However, these conditions are not typical of the Watsonville Slough System, where extensive shallow, stagnant water areas predominate in the spring and summer months. Expansion of the wetland areas of this type would increase the need for mosquito abatement, unless accompanied by improved water circulation and water level control strategies to help combat mosquito breeding cycles.

Water Quality and Biotic Resources

The general public as well as various local, state and federal agencies have an interest in the protection and preservation of water quality and biotic resources in the sloughs. However, the identifiable management practices are largely site specific controls or mitigations imposed on new development projects or waste discharges in the watershed. A synopsis of pertinent water quality and wetland protection policies and regulations (prepared by AMBAG) is included in **Appendix B**. Goals and regulations for wetland preservation and enhancement exist, as do water quality objectives and standards. But, there is no comprehensive program or action plan to achieve the desired water quality and environmental enhancement goals. In general, these goals are aligned with land and water management practices which tend to reduce or eliminate pollutant sources, expand or restore natural environments, and generally provide for safe water quality conditions and a healthy ecosystem.

Section 6.1 of this report provides a listing of established beneficial uses of the waters in the Watsonville Slough System which forms the basis for the Regional Water Board's policies and regulation of water quality in the watershed. Also included in **Section 6.1** is a listing and map of individual facilities which operate under permits ("Waste Discharge Requirements") issued by the Regional Water Board. However, beyond these permitted facilities, the Regional Water Board also has broad authority to take enforcement actions for any identified pollution situation. This is primarily done through the issuance of a "Clean-up and Abatement Order"; but, the Regional Water Board also relies heavily on administrative directives and voluntary compliance whenever possible. The Regional Board also has authority for water quality certification of Clean Water Act (CWA) Section 404 Army Corps permits, pursuant to CWA Section 401. Initial review of water quality certification applications is the responsibility of the Regional Board, and certification is made by the Executive Director of the State Water Resources Control Board.

Another water quality program of note is the planning effort being lead by the Monterey Bay National Marine Sanctuary office. The Water Quality Protection Program (WQPP) implements a key provision of a Memorandum of Agreement adopted by eight federal, state and local agencies in September 1992 when Congress and the President established the Sanctuary. The goal of the WQPP is to restore and maintain the chemical, physical and biological integrity of the Sanctuary. This program, using a watershed approach to address coastal water quality, will investigate a broad range of problems including toxic pollutants in sediments, fish and shellfish; human health problems; sedimentation and low flows in rivers and streams; wetlands alteration and habitat loss.

The Protection Program will develop and carry out a plan containing specific strategies and actions that address these problems while sustaining the region's economic viability. Strategies might include public education, technical assistance, research and monitoring, and regulations and enforcement, where necessary.

One major component of the WQPP will be the development of a Model Urban Runoff Program. Two Model Urban Runoff Ordinances will be drafted addressing water quality issues and possible fee structures. The program will include education and technical training. Another component of the WQPP will be the development of an Agricultural Runoff Management Program.

With respect to wetland restoration and enhancement, there is presently no overall plan or goals that have been established for the Watsonville Slough System. As a result, it is not possible to cite or describe the "optimal" wetland hydrology regime. Many options are possible depending upon the degree of management and control that is exerted over the system. Also, different biological objectives have different water needs. To some, large expanses of open water may be the primary objective for waterfowl. A complexity of shallow and deep water lagoons with seasonal wetlands may be equally or more beneficial biologically. Section 7.4 of this report presents a review of wetland-biological enhancement measures applicable to the Watsonville Slough System. Future wetland enhancement/restoration planning for the Watsonville Slough System (as recommended at the end of this report) can utilize these general guidelines in establishing more specific plans for the system.

Examples of some of the specific wetland restoration/protection projects in the Watsonville Slough System include the following:

- **Harkins Slough**. Harkins Slough has been under a management plan with California Fish and Game for approximately 15 years. This authority was established by agreement with Anderson Peat Company (formerly Old Fort Industries), the owner, and the State Department of Fish and Game. State Fish and Game will become the owner of almost all of the slough between Southern Pacific railroad tracks and the County of Santa Cruz property within approximately five years. A signed deed to Fish and Game is at Santa Cruz Title Company in Santa Cruz. Harkins Slough is not neglected and has significant special management authority presently in place.

- **Hansen Slough**. Hansen Slough is owned primarily by Lee Harkins Ranch, Ltd., (Landmark Real Estate Company, Inc. is the Ranch Manager and its affiliate, Heritage Corporation is the General Partner.) Hansen Slough has been managed by Landmark for the past 15 years. Landmark has been conducting an on-going voluntary management and restoration plan during that time. Hansen Slough cattle grazing and corn farming was stopped when Landmark took over management. All surrounding land is farmed organically and has grass buffer areas around all wetlands. Livestock are fenced out of all wetland areas, and all farming has been stopped in the peat bottom area back to Harkins Slough Road.

  During the past two years, Lee Harkins Ranch, Ltd. Has been working with Dr. John Oliver on an active slough restoration program, which includes:

  (1) Water diversion and retention systems have been created.
  (2) Noxious weeds are being eradicated.
  (3) Willow trees and other wetland natives have been planted.
  (4) Fenced grazing prohibition zones have been implemented.

  All of the work has been financed be Lee Harkins Ranch, Ltd., and Dr. John Oliver's programs. All work has been proactively conducted because of knowledge and desire of conducting slough management stewardship by the property owners and managers.

- **Watsonville Wildlife Area**. This 109-acre wildlife preserve, owned and operated by California Department of Fish and Game is located on the West Branch of Struve Slough. The property is bounded by State Highway 1, Harkins Slough Road, and Lee Road. This property is presently undergoing studies toward the development of a management plan that will define future improvements and appropriate public use.

5.5 WATER BUDGET ANALYSIS

To help understand the occurrence and movement of water through the sloughs a detailed water budget was developed. The water budget is essentially an input-output model that accounts for all of the inflow to outflow from the slough system. It takes into account the rainfall-runoff relationships, groundwater recharge to both the shallow alluvium and deep Aromas aquifer, agricultural irrigation, and evapotranspiration losses. This section describes the methodology and assumptions used to develop the water budget, followed by a presentation and comparison of the results against historic data.

Methodology and Assumptions

The water budget was constructed using monthly time steps. This is consistent with traditional water budget approaches, allows for convenient use of available monthly hydrologic data, and provides the best illustration of seasonal changes in the system.

A schematic flow chart illustrating the various hydrologic parameters and their interrelationships is provided in **Figure 5-6**. Following is a description of the data, assumptions and calculations for each element of the water budget, along with the supporting rationale and general workings of the model.

Rainfall is the driving force in the hydrology and water budget for the sloughs. Average monthly rainfall within the slough system was calculated from 14 years of record based on the Fowles Reservoir rain gage (in Freedom). These averages are presented in **Table 5-2**. The average annual rainfall is approximately 22.5 inches; this is based on 14 years of rainfall data at this station.

- **Runoff**. Rainfall runoff into the sloughs can vary greatly depending on numerous factors including rainfall amount, rainfall intensity, frequency, duration, antecedent soil moisture factors, and soil type. In order to develop the general runoff relationships within the slough system, the SCS TR-55 computer model was utilized. The TR-55 was developed by the U.S. Department of Agriculture, Soil Conservation Service and was designed for analysis of urbanizing watersheds with mixed land-uses. The program was selected for the analysis because it has the ability to estimate total amount of runoff as well as peak storm discharge.

  A key term used in connection with the SCS method is the "Curve Number" (CN). The runoff curve number is a rainfall runoff rating set by the U.S. Soil Conservation Service for use in determining the expected runoff rate from a watershed, based on surface conditions. The larger the curve number, the greater the percentage of runoff for a given rainfall. The

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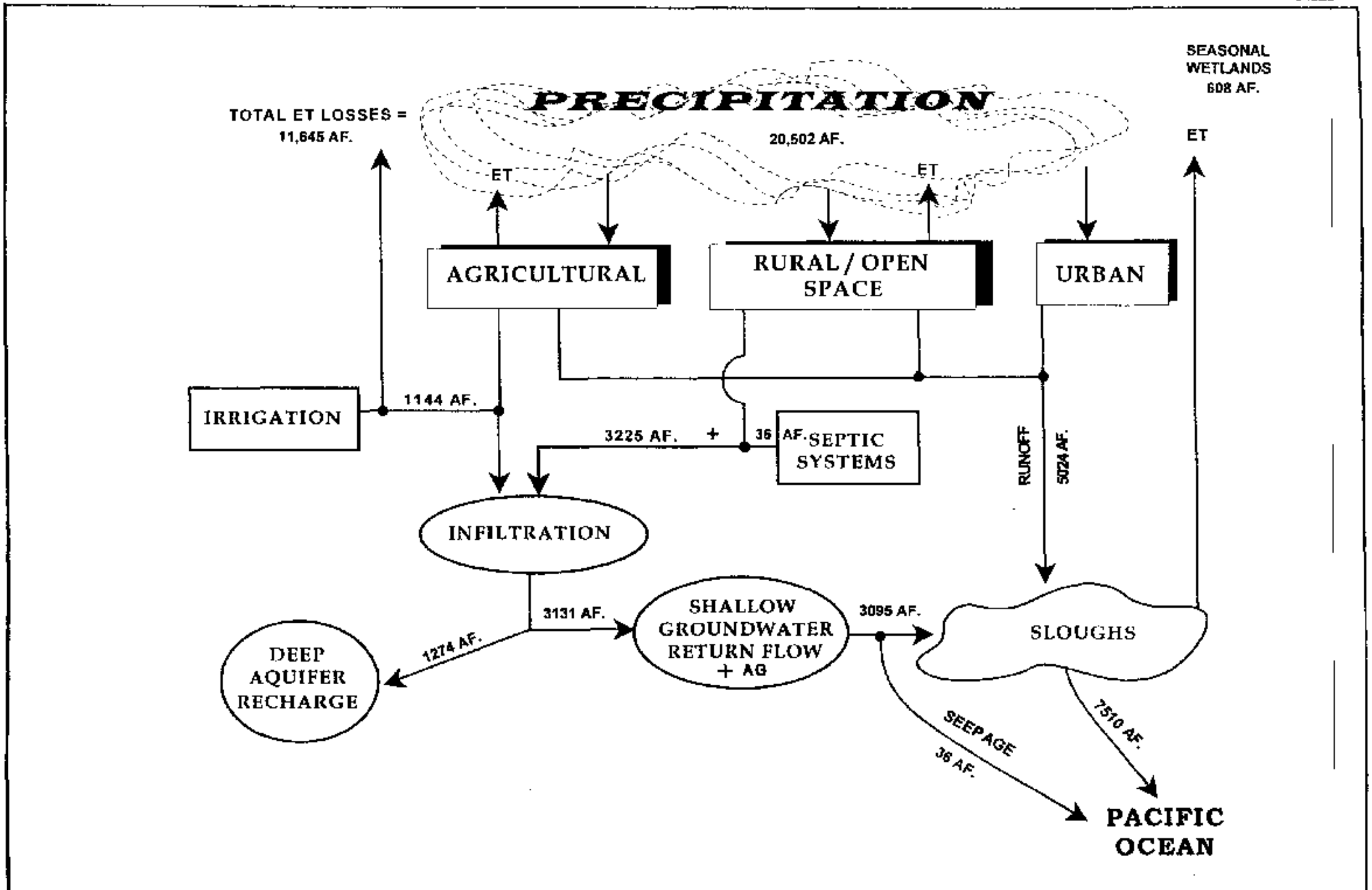


QUESTA ENGINEERING, CORPORATION POINT RICHMOND, CALIFORNIA	**WATSONVILLE SLOUGH SYSTEM** **WATER BUDGET SCHEMATIC**	FIGURE **5 - 6**

TABLE 5-2

Average Monthly Rainfall - Watsonville Slough System Watershed (as measured at Fowles Reservoir, near the Watsonville Airport)

Month	Average Rainfall (inches)
September	0.3
October	1.1
November	3.25
December	3.25
January	4.5
February	3.75
March	4.5
April	1.5
May	0.4
June	0
July	0
August	0
Total	**22.55**

curve number for a particular site is based on vegetative cover, cropping technique, soil properties, and the amount of impervious surface area.

For the water budget analysis, the project area was divided into three separate watersheds: (1) Gallighan Slough; (2) Harkins Slough; and, (3) Watsonville Slough, including Struve, Hanson and West Branch Sloughs. Antecedent soil moisture conditions were accounted for by reducing or increasing the CNs according to procedures described by Schwab, et al (1964). This adjustment was done for all areas except for the impervious surfaces within the watersheds. For fall storms, CNs were adjusted downward to compensate for dry soil conditions; winter storms were modeled with higher curve numbers to simulate saturated soil conditions.

In developing the CN estimates, land uses within the each of the slough watersheds were divided into four categories: urban commercial, urban residential, open space, and agriculture. These categories were further divided into sub-categories based on the underlying soils' hydrologic properties. All categories were then assigned a CN based on land use and soil properties (i.e., the hydrologic soil group described in **Section 5.3**).

With established CNs, the TR-55 program was then used to determine the percentage of runoff from each watershed for various storm rainfall amounts. Historic rainfall records were inspected to determine typical storm rainfall totals during "average" rainfall years. These storms were then used in the TR-55 model to simulate typical storm runoff. Every winter month was simulated by a series of storms that amounted, cumulatively, to the average monthly precipitation. For example, the average rainfall for the month of January, based on 14 years of record, is 4.5 inches. Three storms were simulated dropping 1.0, 1.5, and 2.0 inches of precipitation. Runoff was calculated for each of the storms and was totaled. This total was then compared to average monthly rainfall to calculate the percentage of runoff for the month. Runoff percentage was determined to vary from a high of 72 percent from urban areas to a low of 7 percent from open space with sandy soils. Once the runoff percentage was determined from each land use/soil association in each watershed, all of the computed runoff was totaled to derive the total monthly runoff for the respective watershed.

- **Evapotranspiration Losses**. Rainfall not lost to direct runoff is subject to evapotranspiration. Evapotranspiration refers to the absorption and use of water by plants to respire and photosynthesize, as well as evaporation from the soil.

  For this analysis, the estimated "actual evapotranspiration" rate was used, based upon calculations contained in the U.S. Weather Bureau's "The Climate of Santa Clara and Santa Cruz County" for the Watsonville area. Actual evapotranspiration (ET) is defined as the computed amount of water loss under existing conditions of temperature and precipitation. For the Watsonville area actual ET is approximately 14 inches per year.

- **Deep Groundwater Recharge**. After accounting for runoff and evapotranspiration, the balance of the rainfall percolates into the soil. As previously discussed, portions of the Watsonville Slough System watershed are located over areas which provide recharge to the Aromas Sands aquifer. Rainfall percolating into the soil in these areas is assumed not to return into the slough system, but rather to percolate into the Aromas Sands aquifer which is not hydrologically connected to the slough system. To determine the amount of water within the system which is lost, via recharge to the Aromas Sands, the surface area of these recharge zones was determined (from the County maps) and the percolation component in these areas was subtracted from the overall water budget of the sloughs.

- **Shallow Groundwater Return Flows.** A significant aspect of the slough system is the shallow groundwater return flow. Precipitation that is not lost to runoff or evapotranspiration percolates into the soil and recharges the shallow groundwater of the watershed. Once in the ground the percolating water may either: (a) contribute to the recharge of the deep Aromas Sands aquifer; or, (b) enter the shallow alluvium that eventually discharges into the slough bottoms. Areas not overlying the deep aquifer recharge zones were considered to be sources of shallow groundwater return flow to the sloughs.

  The monthly amount of water entering the shallow groundwater zone was determined simply from rainfall minus the runoff and evapotranspiration components. However, determining the rate at which this groundwater reaches the sloughs was more involved. By examining historic pump station records and comparing them to actual rainfall and estimated runoff rates for the same time period it was determined that there is an approximate 60-day lag between the rainfall peak and the pump discharge peak. It is assumed that this reflects the delayed contribution from shallow groundwater return flow. Accordingly, assuming a normal distribution curve, 25 percent of the percolating water was assumed to reach the sloughs as return flow in 30 days, 50 percent was assumed to discharge in 60 days and the remaining 25 percent in 90 days.

- **Agricultural Return Flows.** The sloughs also receive water inputs that are not associated with precipitation, one of which is irrigation water. In the Watsonville area many crops are grown year-round and many, if not all, of the fields are irrigated during the dry summer months. Farmers use deep groundwater wells for irrigation water. Because the deep Aromas aquifer is not connected to the slough groundwater this irrigation water represents an importation of water into the slough system. The potential evapotranspiration rate (ET) is the amount of water that a given crop or plant uses to photosynthesize and grow. Typically, farmers irrigate their crops beyond the potential ET of the crop in order to flush the soils of salts and other constituents that reduce the productivity of the fields. The excess irrigation water percolates and becomes shallow groundwater return flow. An obvious example of return flows are the extensive tile drains that discharge into Watsonville Slough along Beach Road. These drains collect excess irrigation water that has percolated through the soil and subsequently discharge it into the slough. During the winter the majority of the water collected by these drains is rainfall that has infiltrated through the fields; however, during the irrigation season (generally April to October) these drains are discharging water that has been imported into the slough system from the deep groundwater aquifer.

  To determine the amount of irrigation return flow into the sloughs, it was assumed that in any month that precipitation exceeds the crop ET there is no irrigation and, thus, no agricultural return flow. During the irrigation months, the monthly ET rate (potential) was subtracted from the estimated total monthly irrigation. The difference between ET and irrigation was multiplied by the crop area and from this the amount of return flow (in acre feet) was determined for each crop. These return flows were analyzed by crop and by slough to determine the overall monthly and annual contribution of agricultural return flow to the water budget. Crop irrigation amounts and crop ET rates were obtained from U.C. Agricultural Extension and Pajaro Valley Water Management Agency estimates. A copy of the U.C. reference data is provided in **Appendix C.**

- **Septic System Return Flows**. The majority of the urban and residential areas within the sloughs are within the Watsonville City limits. The sewer service of these areas is supplied by the Watsonville Municipal System. Sewage is delivered to the Watsonville sewage treatment plant for treatment prior to discharge to Monterey Bay via an outfall pipe. However, there are numerous homes and businesses which are not connected to the city sewer system, but instead rely on on-site septic systems. The water that is used for industrial or domestic consumption is either provided by the City of Watsonville, or by groundwater wells. In either case this domestic water can be thought of as imported water in the slough watershed when it is eventually discharged via a septic system. Each home is assumed to discharge approximately 150 gallons per day (on average) into the soil through leachfield systems. It was assumed that there are approximately 250 homes within the watershed area that have septic systems (more precise figures were not readily available from the County's data base system). This equates to approximately three acre feet of wastewater effluent, per month, which is imported into the slough system. Overall, this represents a relatively small percentage of total return flows within the slough system.

Water Budget Results

Using the above described data and assumptions, monthly water budgets (in a spread-sheet form) were constructed for each of the three major watersheds (Gallighan, Harkins and Watsonville Slough). Printouts, by month, for each watershed are provided in **Appendix C**. These individual watershed results were then combined into a single "master" water budget for the entire system, the results of which are presented in **Table 5-3**. The total outflow from the sloughs for average rainfall conditions predicted by the water budget is plotted graphically in **Figure 5-7**. A similar table and graph for the Harkins Slough watershed are provided, respectively in **Table 5-4** and **Figure 5-8**; these would be of importance in assessing any winter diversion recharge scheme for the sloughs. These water balance calculations are for "average" rainfall conditions, based on average monthly rainfall as determined from the Fowles Reservoir rain gauge data (note: average rainfall is based on 14 years of records). In **Figure 5-7** actual monthly pumping data for the Shell Road pump station are plotted for comparison for the 1978-79 and 1979-80 water years. Rainfall in these two years was 21 and 28 inches, respectively; i.e., slightly below and slightly above average conditions.

The water budget results displayed in **Figure 5-7** show reasonably good correlation with actual conditions for the two "near" average rainfall years for which data were available. The general shape of the outflow hydrograph (i.e., showing seasonal trends) is good, as is the cumulative annual runoff. The individual monthly differences result from the difference between actual rainfall totals (represented by the pumping data) and "average" conditions; "average" conditions throughout the

Table 5-3. OVERALL WATER BUDGET FOR THE WATSONVILLE SLOUGH SYSTEM FOR AN AVERAGE YEAR AT THE SHELL ROAD PUMP STATION

MONTH	PRECIP (IN)	PRECIP (AC-FT)	RUNOFF (AC-FT)	GW SEEPAGE LOST (AC-FT)	LOSS TO DEEP GW (AC-FT)	RETURN SHALLOW GW* (AC-FT)	SEPTIC RETURN (AC-FT)	AG RETURN (AC-FT)	ET LOSS FROM SEASONAL WETLANDS (AC-FT)	OUTFLOW OF SLOUGH SYSTEM (AC-FT)
SEPT	0.3	272.8	27.5	0	0.0	0.0	3.0	188.1	43.7	174.8
OCT	1.1	1000.1	100.7	0	0.0	0.0	3.0	117.0	22.1	198.6
NOV	3.25	2954.8	428.6	0	193.2	0.0	3.0	0.0		431.6
DEC	3.25	2954.8	767.5	6	275.3	139.9	3.0	0.0		904.4
JAN	4.5	4091.3	1107.0	6	468.6	295.0	3.0	0.0		1399.0
FEB	3.75	3409.4	1075.4	6	170.4	546.6	3.0	0.0		1619.0
MAR	4.5	4091.3	1107.0	6	166.3	598.6	3.0	0.0		1702.6
APR	1.5	1363.8	342.5	6	0.0	339.3	3.0	131.0		809.8
MAY	0.4	363.7	67.6	6	0.0	31.7	3.0	154.6	160.5	90.4
JUN	0	0.0	0.0	0	0.0	0.0	3.0	227.1	157.3	72.8
JUL	0	0.0	0.0	0	0.0	0.0	3.0	218.7	152.5	69.2
AUG	0	0.0	0.0	0	0.0	0.0	3.0	107.3	72.2	38.0
TOTAL	**22.55**	**20501.7**	**5023.8**	**36.0**	**1273.7**	**1951.1**	**36.0**	**1143.7**	**608.4**	**7510.3**

*Note; "Return Shallow GW" is from rainfall percolation; total shallow groundwater return flow (in figure 5-6) includes "Ag Return" column.
For complete accounting of water inputs and outputs please see the month to month calculations provided in the appendix

Figure 5-7. WATSONVILLE SLOUGH SYSTEM
Water Balance Model Comparison

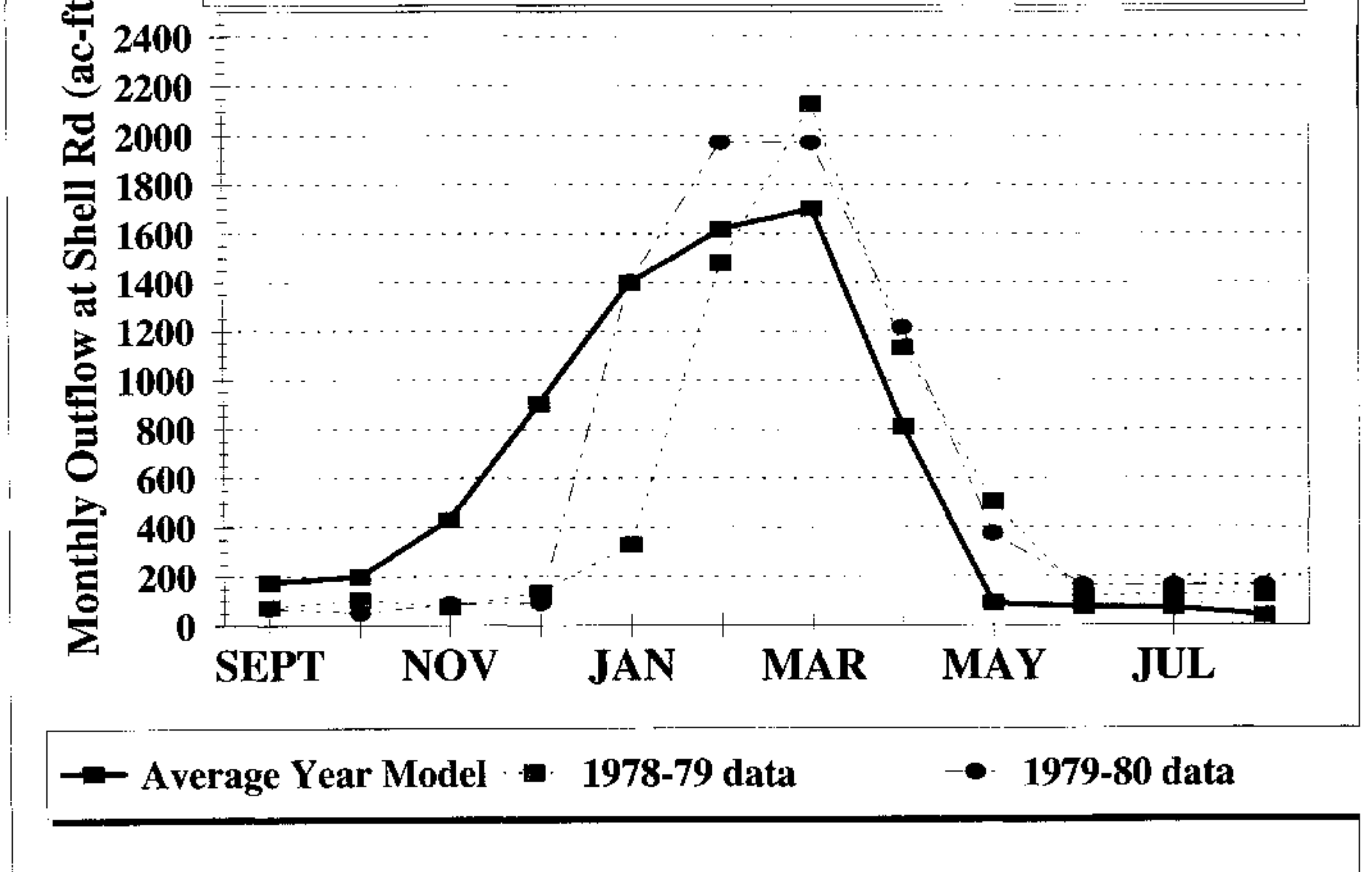
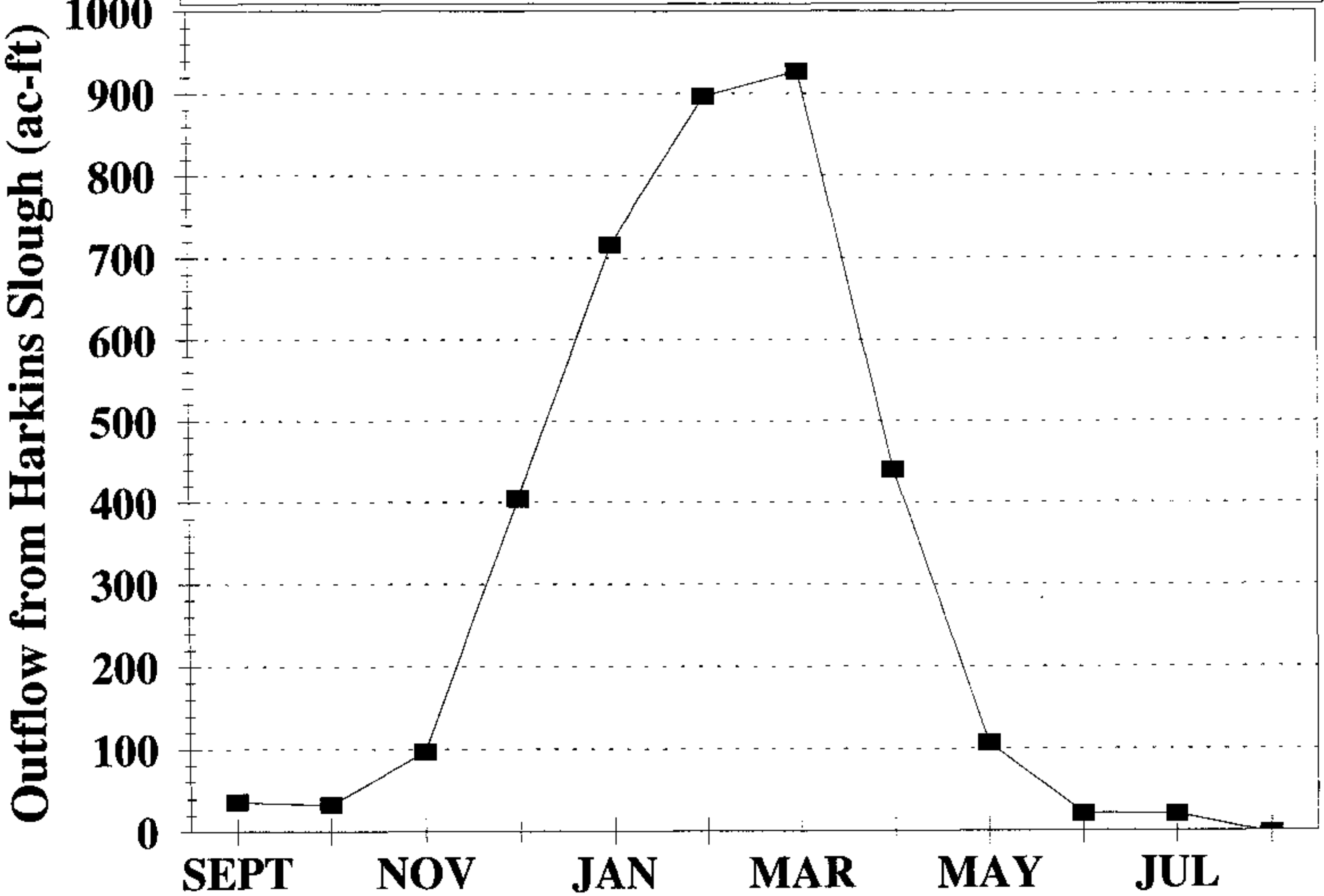


Table 5-4. WATER BUDGET FOR HARKINS SLOUGH FOR AN AVERAGE YEAR AT THE HARKINS SLOUGH PUMP STATION

MONTH	PRECIP (IN)	PRECIP (AC-FT)	RUNOFF (AC-FT)	GW SEEPAGE LOST (AC-FT)	LOSS TO DEEP GW (AC-FT)	RETURN SHALLOW GW (AC-FT)	SEPTIC RETURN (AC-FT)	AG RETURN (AC-FT)	ET LOSS FROM SEASONAL WETLANDS (AC-FT)	OUTFLOW OF SLOUGH SYSTEM (AC-FT)
SEPT	0.3	176.2	2.6	6	0.0	-177.3	3.0	37.6	7.8	35.5
OCT	1.1	645.9	9.7	6	0.0	-88.7	3.0	23.4	3.9	32.2
NOV	3.25	1908.3	93.5	6	193.2	-2.2	3.0	0.0		96.5
DEC	3.25	1908.3	339.8	6	259.4	67.5	3.0	0.0		404.3
JAN	4.5	2642.3	506.5	6	442.1	212.3	3.0	0.0		715.9
FEB	3.75	2201.9	513.8	6	162.3	385.4	3.0	0.0		896.2
MAR	4.5	2642.3	506.5	6	157.8	423.3	3.0	0.0		926.9
APR	1.5	880.8	155.4	6	0.0	261.6	3.0	26.2		440.3
MAY	0.4	234.9	34.5	6	0.0	72.6	3.0	30.9	28.5	106.5
JUN	0	0.0	0.0	6	0.0	-43.4	3.0	45.4	27.9	20.5
JUL	0	0.0	0.0	6	0.0	-50.3	3.0	43.8	27.1	19.7
AUG	0	0.0	0.0	6	0.0	-76.7	3.0	6.1	12.8	-3.8
TOTAL	**22.55**	**13240.6**	**2162.4**	**72.0**	**1214.7**	**984.2**	**36.0**	**213.4**		**3690.4**

Figure 5-8. Estimated Month to Month Outflow From Harkins Slough



year rarely occur. It should also be noted that substantial land use changes (especially expansion of the urban area) have occurred in the watershed since the late 1970s, adding further uncertainty to these comparisons with historic runoff data. Also, the pumping data themselves are estimates based upon electrical use records; they do not account for gravity outflow (through tide gates or over the top of Shell Road) which can occur from time-to-time when slough water levels are very high. No information was available to determine how often this might occur and how much outflow it would represent. Overall, the water budget gives a reasonable picture of the slough hydrology and can be used to test different management strategies that may affect water flow and occurrence in the watershed.

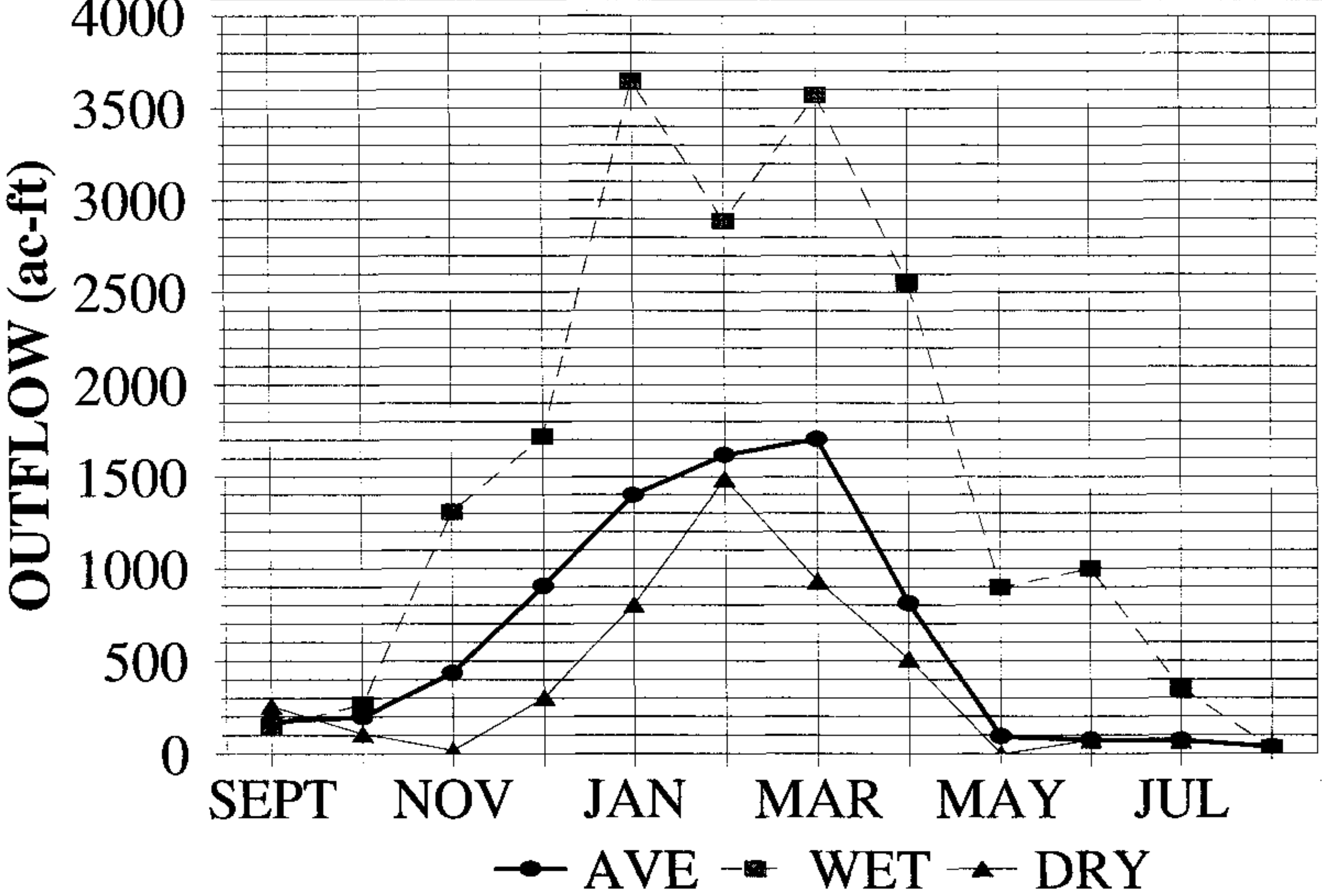
After validating the water balance model for average conditions, computations were also made for representative "wet" and "dry" year conditions. Actual rainfall data for 1981-82 and 1986-87, respectively, were selected for the wet and dry year simulations. The results are plotted in **Figure 5-9**, along with the average year results. The only modifications in the water balance made for these calculations was in the wet year scenario; the irrigation season was assumed not to start until May, and the areas used for calculation of wetland ET was increased by 10 percent. Water balance calculations are provided in **Appendix C**. The total annual rainfall for the 1981-82 wet year was 39.4 inches; the rainfall for the 1986-87 dry year was 14.4 inches.

These additional wet and dry year hydrologic simulations for the watershed reveal the following:

- In wet years, the groundwater return flow into the sloughs has a substantial effect well into the summer; irrigation return flow does not dominate until late summer and early fall (e.g., August-September). This implies substantially better water circulation and water quality conditions except for two or three months during the year.

- In dry years irrigation return flow dominates the flow regime beginning early in the spring, and extends through the fall. Poor water flow, stagnant conditions and poor water quality may exist for over half the year. However, even in dry years significant winter runoff and flow through the sloughs occurs, nearly to the same level as in average rainfall years.

Figure 5-9. OUTFLOW COMPARISON FOR AVERAGE, WET, AND DRY RAINFALL YEARS



SECTION 6

WATER QUALITY INVESTIGATION

This section presents the results of the water quality investigation conducted for the management plan. The purpose of the investigation was to review historic water quality information and to augment these data with additional monitoring to fill "data gaps" and expand the overall understanding of water quality conditions in the sloughs.

6.1 BACKGROUND WATER QUALITY INFORMATION

Beneficial Uses

Definition and designation of beneficial uses of water resources is a fundamental aspect of the State's water quality protection and management program. Designated beneficial uses provide the basis for determining appropriate water quality standards and protection criteria for given water bodies. **Table 6-1** lists the designated beneficial uses (all of which are existing uses) for the Watsonville Slough System, as adopted in the February 1994 amendments to the Water Quality Control Plan for the Central Coast Basin. Definitions for the applicable beneficial use categories are noted below the table. As indicated by these designations, in-stream recreational and habitat uses are extensive and cover all defined use categories. The Watsonville Slough System has no present uses (or designation) as a source of water supply; but the potential for water diversion from Harkins Slough for water supply and groundwater recharge (per the plan being studied by the PVWMA) may warrant a change in this beneficial use designation.

WATER QUALITY

Historic Water Quality Findings

Degraded water quality conditions in the Watsonville Slough System have been documented by several studies over the past 15 to 20 years, including on-going monitoring by the County of Santa Cruz and periodic sampling by the Regional Water Board. Identified problems include those associated with pesticide accumulation in sediments and aquatic organisms, high nutrient levels, localized algal blooms and, periodically, low dissolved oxygen and toxic levels of ammonia. The findings from tissue sampling of aquatic organisms as well as water column testing are summarized here.

TABLE 6-1

DESIGNATED BENEFICIAL USES FOR WATSONVILLE SLOUGH SYSTEM

WATER BODY	BENEFICIAL USES														
	MUN	AGR	PRO	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIO	RARE	EST.
WATSONVILLE SLOUGH						X	X	X		X		X	X	X	X
Struve Slough						X	X	X	X		X	X	X	X	X
Hanson Slough						X	X	X		X		X	X	X	X
Harkins Slough						X	X	X		X		X	X	X	X
Gallighans Slough						X	X	X		X		X		X	X

DEFINITIONS

Source: Amendment of the Central Coast Water Quality Control Plan, February 1994.

MUN - **Municipal and Domestic Supply**. Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

AGR - **Agricultural Supply**. Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

PRO - **Industrial Process Supply**. Uses of water for industrial activities that depend primarily on water quality.

IND - **Industrial Service Supply**. Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydrauli conveyance, gravel washing, fire protection, or all well repressurization.

GWR - **Ground Water Recharge**. Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusio into freshwater aquifers.

REC1 - **Water Contact Recreation**. Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but ar not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

REC2 - **Non-Contact Water Recreation**. Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of wate is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beach combing, camping, boating, tidepool and marine life study, hunting, sightseeing or aesthetic enjoyment in conjunction with the above activities.

WILD - **Wildlife Habitat**. Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

COLD - **Cold Freshwater Habitat**. Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife including invertebrates.

WARM - **Warm Freshwater Habitat**. Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.

MIGR - **Migration of Aquatic Organisms**. Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

SPWN - **Spawning, Reproduction and Early Development**. Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

BIO - **Preservation of Biological Habitats of Special Significance**. Uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS), where the preservation or enhancement of natural resources requires special protection.

RARE - **Rare, Threatened, or Endangered Species**. Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.

EST - **Estuarine Habitat**. Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlif (e.g., estuarine mammals, waterfowl, shorebirds).

Tissue and Biotic Sampling

The most significant water quality concern in the Watsonville Slough System has been the accumulation of pesticides and PCBs, which have appeared at elevated concentrations in tissue sampling of fish and invertebrates (SWRCB, June 1991). The tissue sampling occurred between 1984 and 1993 as part of the State Mussel Watch (SMW) and Toxic Substances Monitoring (TSM) programs. During this period, twenty-one tissue samples from the Watsonville Slough System were analyzed for numerous toxic substances. Eleven of the twenty-one samples exhibited levels of one or more pesticides and/or PCBs that exceeded the National Academy of Sciences (NAS) recommended guidelines for aquatic organisms. The pesticides for which NAS guidelines were exceeded include DDT, Chlordane, Dieldrin, Endosulphan, Toxaphene, and Hexachlorobenzene (see **Section 6** and **Appendix D** for a summary of the SMW and TSM results). Some of the highest levels of pesticide contamination found in California by the TSM and SMW programs occurred in the Watsonville Slough System.

Fish tissue samples from Harkins Slough and Watsonville Slough were analyzed on a nearly annual basis between 1984 and 1988 under the SWRCB Toxic Substances Monitoring Program (TSM) Program. As noted above, the testing has shown high levels of several pesticides, including chlordane, DDT, dieldrin, endosulfan and toxaphene. In nine of the ten TSM samplings, the detected levels of one or more of these pesticides have exceeded guidelines established by the National Academy of Sciences (NAS) for toxic substances in fish. The NAS guidelines are intended to protect the fish as well as other species that consume the fish. The findings of the fish tissue sampling under the TSM program have been the basis for the SWRCB's designation of Watsonville Slough as an impaired water body.

Watsonville Slough has also been included in sampling under the California State Mussel Watch (SMW) Program between **1982 and 1993.** Several different sampling points in Watsonville Slough and Harkins Slough have been monitored using freshwater clams. Tissue samples from clams are used as indicators of water quality problems because of the bioaccumulation of pollutants within the organism. This method of pollution study is followed because concentrations of many toxic substances are often too low or transitory to be reliably detected through traditional sampling of the water column. Also, many toxic compounds are not water soluble, but are found associated with sediment or organic matter. The findings from the SMW are important in understanding the water quality conditions in areas where toxic substances may be present. The results do not provide absolute values on toxic pollution in water; however, they are useful as an indicator of trends over time and in comparison with other water bodies.

The results of the SMW sampling for Watsonville Slough and Harkins Slough have shown extremely elevated levels of several toxic organic substances. Specifically, samples have exceeded the EDL 95 for dacthal, DDT, dieldrin, endrin, endosulfan and toxaphene. The "EDL 95" stands for Elevated Data Level-95th percentile, based on the complete array of data collected statewide under the SMW. This means that the concentrations have been within the highest five percent of all values recorded in the SMW program over the past 15 years. The SMW results for the Watsonville Slough system also exceeded the NAS guidelines for DDT in 1986 and again in 1993.

In addition to the noted tissue sampling studies, results of benthic invertebrate surveys in the lower, tidally-influenced portion of Watsonville Slough have demonstrated low species diversity and concentrated populations of pollution-tolerant organisms (*personal communication, Dr. John Oliver, September 1992*). Contaminated shellfish and animal tissue samples indicate potentially adverse effects on recreational fishing and hunting within the slough system. In the early 1980s, a fish-kill occurred in Harkins Slough which was believed to be caused by observed toxic levels of ammonia, the source(s) of which was not confirmed (*personal communication, John Ricker, May 1995*).

Presently, aquatic toxicity studies in the Watsonville Slough System are and the lower Pajaro River being conducted by researchers at the University of California, Santa Cruz (UCSC); but there are no published results that were available for review and incorporation into this project (*personal communication, Brian Anderson, U.C.S.C., March 1995*). Future studies and water quality planning for the Watsonville Slough System should be coordinated with this ongoing UCSC research and should make use of the results.

Water Quality Monitoring

Since the late 1970s several different locations in the Watsonville Slough System have been monitored for water quality by various entities, including the Central Coast Regional Water Board, Santa Cruz County, the City of Watsonville, and the operators of the two landfills in the watersheds. Standard sampling locations have included Watsonville Slough near San Andreas Road and in the tidally-influenced reach below the outfall from the Beach Road Ditch. Limited data have also been collected periodically at the Shell Road pump station, on Galligan Slough (downstream of the landfills) and at spot locations on Harkins and Struve Slough and the upper portion of Watsonville Slough near the urban area.

Despite the findings of toxic organic accumulation in the fish and shellfish tissues, historic water column data for Watsonville Slough near San Andreas Road and at the Shell Road pump station generally indicate acceptable water quality for warm water aquatic organisms as indicated by the following standard parameters.

- **pH**. The pH is consistently within the range of six to nine.

- **Temperature**. Temperature in the sloughs varies seasonally, with winter time lows of about 10°C (50°F) and summer-time highs up to about 25°C (77°F).

- **Dissolved Oxygen (DO)**. The DO levels are generally in the acceptable range of 5 to 10 mg/l; but occasionally DO has been monitored at extremes of less than 3.0 mg/l, and also as high as 18 to 20 mg/l, indicating a probable diurnal fluctuation due to algae growth. Low dissolved oxygen is not uncommon in normally functioning wetland areas; and the observed fluctuations may not necessarily be indicative of a water quality problem. The historic data do not indicate any widespread or chronic DO problems; however, there are likely localized areas of shallow and/or stagnant water where DO levels may be depressed due to algae production. Delineation of these areas would require comprehensive DO surveys throughout the sloughs during the warm summer season; and, to date, this has not been done.

- **Turbidity and Suspended Solids**. Turbidity levels in the sloughs vary widely, from less than 1.0 JTU to more than 100 JTU (note: JTU stands for Jackson Turbidity Units). Values in the range of 10 to 50 JTU are most common, which is fairly turbid but not uncharacteristic for sloughs. Suspended solids concentrations (for which there is limited data) also vary widely, from less than 10 mg/l to more than 700 mg/l. The highest levels reported were for winter sampling events, indicating the influence of soils and other particulate matter contained in storm runoff.

- **Nutrients**. Nutrient levels (specifically nitrogen compounds) have historically been very high in the Watsonville Slough System. Nitrate levels have been found typically in the range of 10 to 70 mg/l (as NO_3), dropping to less than 5.0 mg/l at times. Total nitrogen concentrations of 5 to 15 mg/l are common. These observed nutrient levels are very high by most standards for natural waters. But, algae growth is not apparently a widespread phenomenon or problem in the slough system, and factors other than nitrate must be limiting the growth (e.g., light penetration, substrate water temperature, etc.). Further study is needed of the nutrient-algae relationships in the slough system to determine how nitrate concentrations are of any significance to water quality.

- **Ammonia**. Ammonia concentrations in the sloughs have been found at potentially toxic levels, sometimes as high as 2 to 4 mg/l. Most results are in the range of 0.1 to 1.0 mg/l. Ammonia toxicity is dependent upon the pH and temperature of the water (which determines the unionized, NH_3, fraction). Data for the Watsonville Slough System show routine exceedance of the chronic ammonia toxicity limit of 0.02 mg/l (NH_3), which is for the protection of sensitive fish species. The one reported fish kill in the slough system was suspected to being related to very high ammonia levels; but elevated ammonia levels have occurred at other times without any apparent fish kills. Therefore, the cause of the high ammonia levels as well as the tolerance of the aquatic organisms in the slough system to ammonia needs further investigation.

- **Heavy Metals**. Historical data for heavy metals in the Watsonville Slough System is very sketchy. Of the few metals analyzed, only copper has appeared routinely at concentrations that exceed criteria for freshwater and saltwater aquatic organisms. No study of the specific sources of copper or the local aquatic toxicity effects has been completed to determine if the observed concentrations represent an on-going problem and serious threat to the aquatic organisms in the slough system.

- **Pesticides**. Pesticide water quality data for the Watsonville Slough System are very limited. No detection of pesticides in water column samples has been reported, despite the high pesticide concentrations found in aquatic organisms. As noted earlier, this may be due to the fact that pesticides adhere to soil particles and tend to rapidly settle out rather than remain in the water column.

- **Fecal Coliform**. Sampling in the Watsonville Slough System for coliform has been conducted by Santa Cruz County from time to time. Results of routine sampling of several different stations for the period of July 1994 - July 1995 are provided in **Appendix D**. Included are stations on Watsonville Slough Struve Slough and Harkins Slough. Spot measurements taken in 1987 - 1992 are also listed. The data show a range of results, typically from <100 MPN/100 ml to about 1,000 MPN/100 ml. There are also a few isolated readings in the range of 2,000 to >11,000 MPN/100 ml. About half of the results exceed 400 MPN/100 ml, which is the maximum limit for water contact recreation waters. As another point of reference, samples taken by the PVWMA in April 1995 showed readings of 43 and 240 MPN/100 ml, respectively, at Harkins Slough (Pump Station) and Watsonville Slough (upstream of Harkins Slough). Generally the coliform data show significant coliform levels in the sloughs that are likely the result of animals and waterfowl; but there could also be input from septic systems or sewage overflows from the urban area. No surveys or site specific sampling has been done to determine the sources of high coliform readings in the sloughs.

Historical data for the lower, tidally-influenced reach of Watsonville Slough conforms very closely to the above-described conditions for the freshwater portion of the sloughs. The only noticeable differences are with regard to mineral content; salinity (i.e., electrical conductivity and total dissolved solids) values for the tidal area are routinely higher, as would be expected because of the brackish conditions.

In summary, the historic data for the Watsonville Slough System show convincing evidence of toxic organic accumulation in fish and shellfish residing in the waters; and, these findings are the basis for the SWRCB's designation of the slough system as an impaired water body. On the other hand, the water column data show generally acceptable water quality for warm water aquatic species, with occasional incidences of low DO, high (toxic) levels of ammonia, and elevated copper concentrations. None of these appear, from historic data, to be chronic conditions that on their own would merit designation of the slough system as an impaired water body. Nevertheless, they do represent existing or potential water quality problems that, at least periodically, affect aquatic habitat conditions in the slough system.

Potential Pollutant Sources

The potential sources of contamination in the Watsonville Slough System include erosion (which can transport contaminants that adhere to soil particles) agricultural return flows, animal wastes, landfill leachate, on-site sewage disposal systems, sewage spills, and urban runoff. The slough drains a 21-square mile watershed in south Santa Cruz County, including four square miles of urban lands within the City of Watsonville. A listing of the various point source discharges within the watershed that presently operate under Waste Discharge Requirements adopted by the Regional Water Board is provided in **Table 6-2**. A map showing their respective locations in the watershed is provided in **Figure 6-1**.

Based on background watershed studies and input obtained from TAC meetings and workshops, the following specific land use activities have been identified as being potential contributors of pollutants to the Watsonville Slough System. It should be understood, however, that no water sampling was conducted at or around any of these particular sites as part of this project to verify the nature or

TABLE 6-2

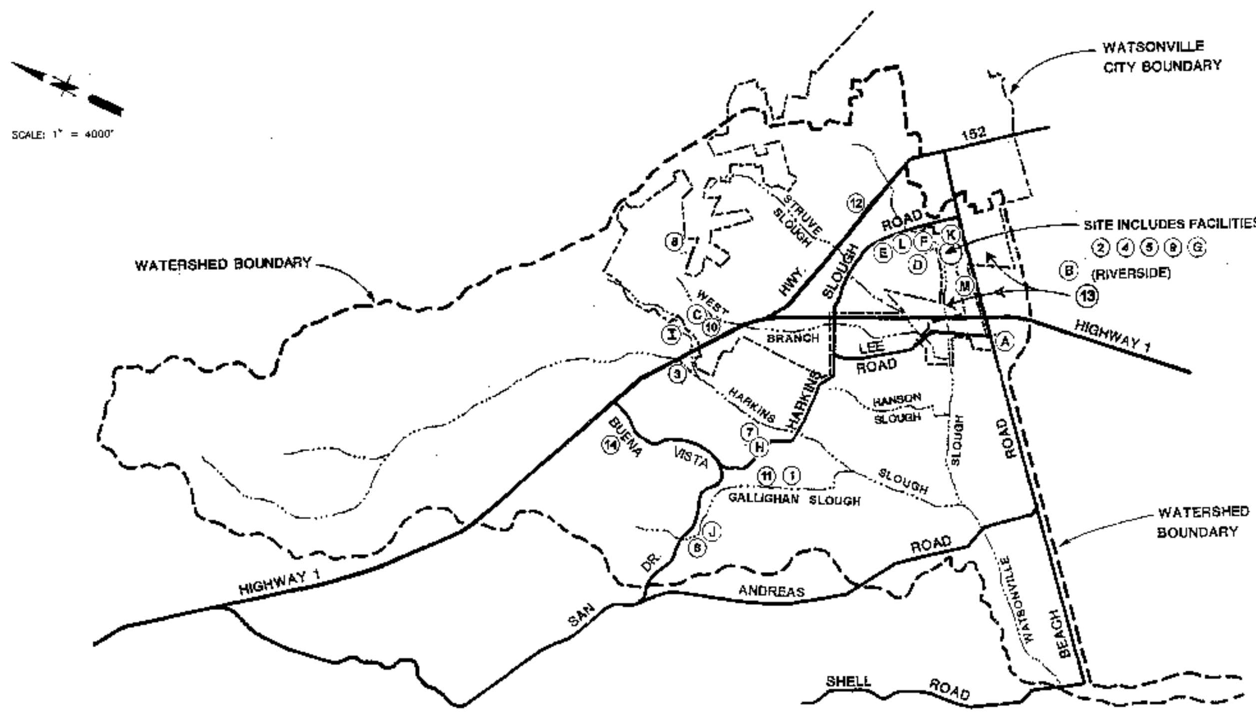
EXISTING WASTE DISCHARGE FACILITIES IN WATSONVILLE SLOUGH WATERSHED

KEY	NAME OF FACILITY	PERMIT TYPE AND NUMBER
RWQCB Waste Discharge Permittees (Groundwater Discharge)		
1	Santa Cruz County Medium Security Jail	WDR Order No. 91 - 33
2	California CoPackers Corporation	WDR Order No. 91 - 78 (NPDES No. CA 004 9662)
3	Western Farm Services (Greengro Facility)	WDR Order No. 90 - 63
4	Western Farm Services (Watsonville Facility)	WDR Order No. 90 - 67
5	Phillips Driscopipe	WDR Order No. 90 - 03 (NPDES No. CA 004 8330)
6	Watsonville Class III Landfill	WDR Order No. 94 - 02
7	Santa Cruz County Buena Vista Landfill	WDR Order No. 90 - 005
8	Exxon Company, United Flight Service	WDR Order No. 90 - 105
9	Apple Growers Ice & Cold Storage Company	WDR Order No. 93 - 10 (NPDES No. CA 004 7708
10	Spectra-Mat	WDR Order No. 89 -123 (NPDES No. CA 004 8976)
11	Buena Vista Migrant Farm Labor Camp	WDR Order No. 93 - 118
12	Ultramar	WDR Order No. 87 - 118
13	Richard Shaw/Dean Foobs	WDR Order No. 89 - 120
14	Matthew & Sons Mushrooms	WDR Order No. 86-218
NPDES Industrial Stormwater Permittees (Surface Water Discharge)		
A	Columbia Pacific Aluminum Corporation	NPDES No. 344S 00 1723
B	Dean Foods	NPDES No. 344S 00 2995
C	HADCO	NPDES No. 344S 00 3579
D	Farmer's Processing	NPDES No. 344S 00 1662

TABLE 6 - 2 (cont'd)

EXISTING WASTE DISCHARGE FACILITIES IN WATSONVILLE SLOUGH WATERSHED

NPDES Industrial Stormwater Permittees (Surface Water Discharge)		
E	New West Food	NPDES No. 344S 00 9683
F	Norcal-Crosetti	NPDES No. 344S 00 0105
H	Santa Cruz Buena Vista Landfill	NPDES No. 344S 00 1258
I	Watsonville Airport	NPDES No. 344S 00 3032
J	Watsonville Class III Landfill	NPDES No. 344S 00 3031
K	Watsonville Concrete	NPDES No. 344S 00 6080
L	Watsonville Co-Generation Facility	NPDES No. 344S 00 2233
M	West Coast Circuits	NPDES No. 344S 00 4243
NPDES Industrial Process Water Permittees (Surface Water Discharge)		
2	California Co-Packers Corporation	NPDES No. CA 004 9662
5	Phillips Driscopipe	NPDES No. CA 004 8330
9	Apple Growers Ice & Cold Storage	NPDES No. CA 004 7708
10	Spectra-Mat	NPDES No. CA 004 8976



NOTE:

SEE TABLE 6-2 FOR KEY TO FACILITY NUMBERS AND LETTERS

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POINT RICHMOND, CALIFORNIA

WATSONVILLE SLOUGH SYSTEM
EXISTING WASTE DISCHARGE FACILITIES IN WATSONVILLE SLOUGH WATERSHED

FIGURE
6-1

extent of any actual water quality impacts from these facilities. They are listed here simply to give a better understanding of the activities and sources that could produce water quality impacts on the slough system.

- two landfills;
- mushroom growing facilities (e.g., one just west of Lee Road and north of Struve Slough);
- two wrecking yards; (one on the east side of Lee Road just north of Watsonville Slough channel, and the other off Errington Road on the east shore of the upper Watsonville Slough wetland area south of Harkins Slough Road);
- farm chemical distribution facility in upper Harkins Slough;
- industrial land uses along West Beach Street and Lee Road; with occasional spills;
- self-serve car wash facility on the north side of Main Street, just west of the Watsonville Slough channel (where people sometimes dump used motor oil);
- confined animal facilities (in particular, the one in the headwaters area of Hansen Slough north of Harkins Slough Road, which drains into both Hanson and Harkins Sloughs);
- Watsonville Airport, which drains into the upper portions of Struve and possibly Harkins Sloughs; and,
- major commercial uses around the intersection of Green Valley Drive and Main Street, which have large parking areas that drain into Struve Slough.

6.2 WATER QUALITY MONITORING PROGRAM DESIGN

Quality Assurance Project Plan

Prior to undertaking the water quality monitoring work a Quality Assurance Project Plan (QAPP) was prepared. The QAPP was prepared according to guidelines described in "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans" (EPA Document 600/4-83004, February 1983). A QAPP is a written document which presents, in specific terms, the policies, organization (where applicable), objectives, functional activities, and specific quality assurance (QA) and quality control (QC) activities designed to achieve the data quality goals of a specific project(s) or continuing operation(s). The QAPP is required for each specific project or continuing operation (or group of similar projects or continuing operations). The QAPP is typically prepared by the responsible program office, regional office, laboratory, contractor, grantee, or other organization, and reviewed and approved by the oversight agency (in this case the State Water Resources Control Board). The QAPP for this project was completed in August 1994, copies of which are on file with AMBAG, the SWRCB and the Department of Fish and Game (Monterey Office).

Sampling Stations

The field sampling stations were located following compilation and review of historic water quality data. The sampling stations were selected to verify previous data trends and to fill "data gaps" with respect to geographic needs and uncertain water chemistry. In general, the objective was to gather information for all sub-watersheds. The selection of sampling stations considered the following:

- Proximity to potential contaminant sources of interest;
- Access and safety considerations;
- Defined channel conditions; and,
- Historic data.

Following is a description of the ten sampling stations selected for inclusion in the monitoring program. The station designation (e.g., "A44" etc.) was based upon the conventions established in previous water quality sampling programs in the watershed. A map showing the location of the various sampling stations is provided in **Figure 6-2**.

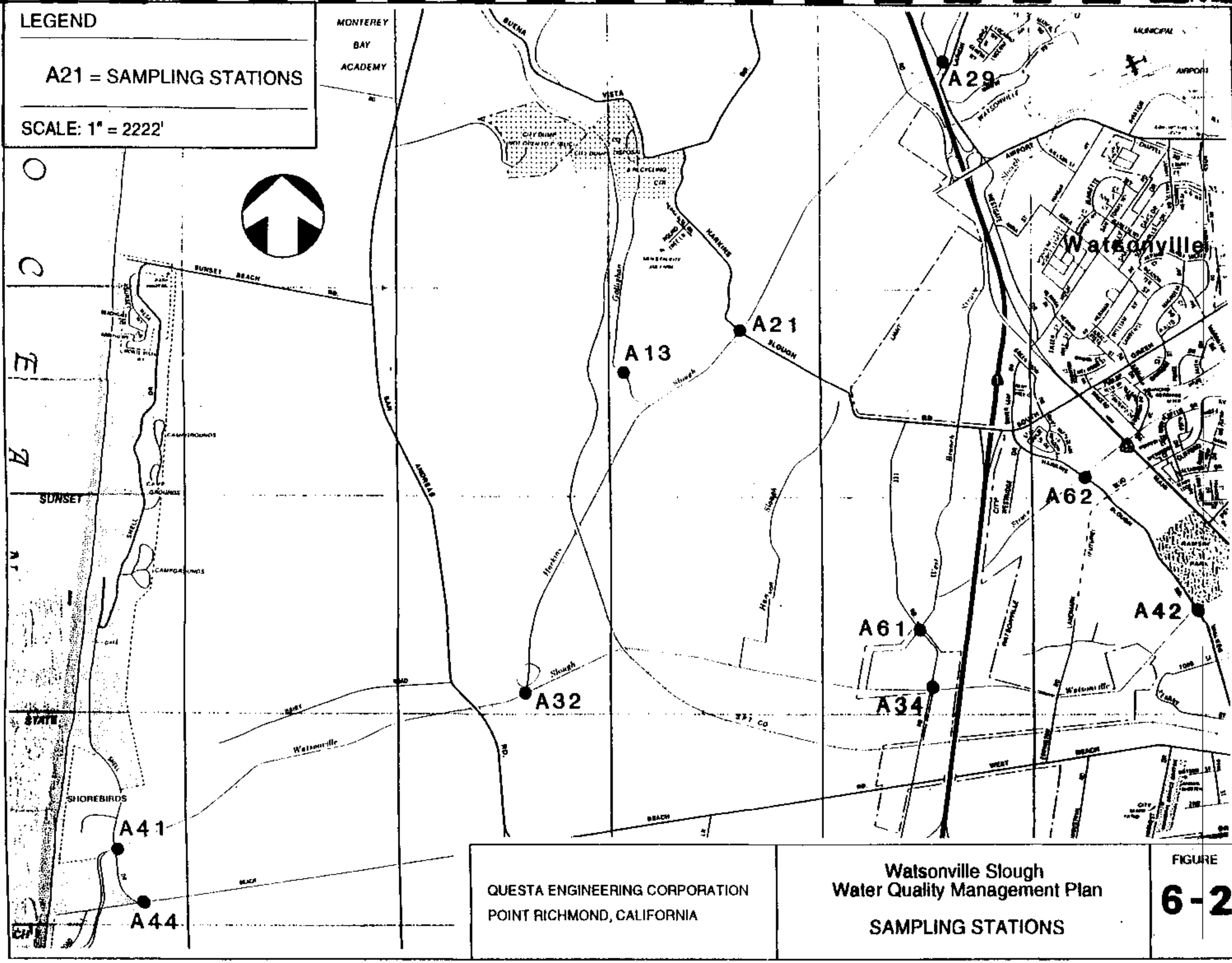
- **Station A44 (Beach Road)** - This sampling site was located in the Beach Road drainage ditch near the intersection of Beach Road and Shell Road. The ditch runs parallel to Beach Road and drains the irrigation runoff and discharge from tile drains from the agricultural fields located primarily to the south of Beach Road. The ditch is a man-made open earthen channel. A sump pump discharges pulses of agricultural runoff from field tile drains directly into the irrigation ditch at the sampling site. The Beach Road drainage ditch and discharges directly into the tidally influenced portion of Watsonville Slough.

- **Station A41 (Shell Road)** - This sampling site was located at the Shell Road pump station on Shell Road. The Shell Road pump station discharges accumulated runoff in the Watsonville Slough System across Shell Road and into the tidal/estuarine portion of Watsonville Slough. The samples were taken at the upstream face of the pump station. Agricultural fields line Watsonville Slough immediately upstream of the site. This sampling station represents the integrated effect of runoff from all land uses in the watershed.

- **Station A32 (San Andreas Road)** - This sampling site was located in Watsonville Slough upstream of its confluence with Harkins Slough, just east of San Andreas Road. Harkins Slough discharges into Watsonville Slough via the Harkins Slough pump station. This portion of the Watsonville Slough is an open earthen channel without vegetative cover which receives direct runoff and tile drainage from the surrounding agricultural lands. In addition to the immediately bordering agricultural lands, sampling at this site represents the combined runoff from Watsonville urban area and other agricultural lands draining to Watsonville, Hanson, West Branch and Struve Sloughs.

- **Station A21 (Harkins Sl.)** - This sampling site was located at the crossing of Harkins Slough by Harkins Slough Road. The samples were taken on the north side of the road. This portion of Harkins Slough is comprised of a large, broad wetland with extensive ponding and seasonal flooding. The contributing watershed includes hillside and lowland agricultural uses which border the slough, plus the rural residential and open space areas of the Larkin Valley.

- **Station A13 (Gallighan Sl.)** - The sampling site was located at 629 Harkins Slough Road in the upper portion of Gallighan Slough. The samples were taken in the active open channel of the slough. The immediate area of the sampling site is dominated by riparian forest comprised of Arroyo willows and associated wetland vegetation. The contributing



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POINT RICHMOND, CALIFORNIA

Watsonville Slough
Water Quality Management Plan

SAMPLING STATIONS

FIGURE
6-2

watershed area includes the County and City landfills, hillside agriculture and large on-site wastewater disposal facilities for local housing and the County jail.

- **Station A29 (Larkin Valley)** - The sampling site was located in the upper Harkins Slough between Racehorse and Moon Valley Ranch Roads just off of Larkin Valley Road. There exists a large cement culvert which directs surface runoff under Highway 1 and into the open channel of Harkins Slough. Harkins Slough parallels Larkin Valley Road and continues south. The channel in this area is an incised drainage ditch lined by native vegetation and trees. The contributing watershed largely rural residential with scattered small agricultural uses and open space. Limited sampling was completed at this station due to the lack of runoff except during the larger flow events.

- **Station A34 (Watsonville Sl. @ Lee Road)** - The sampling site was located at the intersection of Lee Road and Watsonville Slough where large culverts allow a continual flow of water within the slough. The open channel has rather steep banks lined with grasses and exposed soil. The land uses in the site vicinity are primarily urban-industrial with some agriculture. The samples were taken on the west side of the Lee Road overpass.

- **Station A61 (Lower Struve Sl.)** - The sampling site was located at the crossing of Struve Slough and Lee Road. The sampling area is a flat, seasonally-ponded wetland. This region of Lee Road is subject to flood inundation during the winter and spring. The level elevation of the vicinity along with the inputs of both West Branch and Struve Slough creates a large area of ponding. The samples were taken on the northwest side of Lee Road near the road culverts. The watershed upstream from this point includes the highway and urban, residential and commercial land uses above the large wetland area.

- **Station A62 (Upper Struve Sl.)** - The sampling site was located at the crossing of Harkins Slough Road and upper Struve Slough. A series of small culverts convey the water underneath the road. The slough is dominated in wetland vegetation at this location. Seasonal ponding occurs in this portion of Struve Slough. The samples were taken downstream of the culverts on the south side of Harkins Slough Road. This sampling site receives intermittent runoff from an urban area, upstream of the large wetland area sampled by Station A61.

- **Station A42 (Upper Watsonville Sl.)** - The sampling site was located at the intersection of Harkins Slough Road and Watsonville Slough. This portion of Watsonville Slough is a broad open natural channel filled and lined with wetland vegetation. The samples were on the downstream side of Harkins Slough Road. This sampling site receives runoff from a large urban area of Watsonville.

Water Quality Sampling Procedures

Surface water samples were collected by either subsurface grab samples, utilizing cleaned/unused polypropylene containers, or manually depth-integrated samples (see below) collected at various fixed points across defined channel sections. The appropriate preserved aliquots (i.e., bottles) were filtered and filled in the field and transported to the laboratory facility. Additionally, field blanks, duplicate and split samples were delivered to the analytical laboratories for quality control (QC) purposes.

Adhesion of pesticide residue to sediment, and the eventual movement of these sediment particles off the treated fields, has been demonstrated (*Wauchope, 1978, Weaver et al, 1990*). This transport mechanism may play a significant role in the eventual fate of pesticide applied to a field. Based on this information, it was determined to be important to collect representative samples of suspended sediment in slough waterways. This was done with the use of depth-integrating samplers which allows for uniform collection of water and sediment through a given section of a stream. The sampling device used for this was the hand-held modified DH-48 sampler (developed by Burgy, 1972) which was adapted to allow the use of plastic or glass sample bottles and a rigid extension rod for immersion in the streamflow.

Sampling was conducted at the end of the dry season and during, or soon after, major storm events during the fall and early winter of 1994. Water quality sampling was completed for one non-storm period (September 1994) and for three runoff events. But, only a limited amount of sampling was conducted during October due to the very low amount of runoff generated.

Analytical Methods

The water quality analysis included field characterization for physical parameters, and laboratory analysis for nutrients and selected metals and pesticides. All laboratory chemical analysis was completed by accredited laboratories under the California Environmental Laboratory Accreditation Program (ELAP) and using approved EPA methods or, in the case of some pesticide compounds, methods developed and approved by the California Department of Food and Agriculture (CDFA). Physical parameters (e.g., sediment, field measurements) followed the recommended procedures of the U.S. Geological Survey. Analyses were completed for the following parameters:

- **Physical Parameters**. pH, conductivity, temperature, turbidity, and dissolved oxygen measurements were completed in the field. Total suspended solids (TSS) and total dissolved solids (TDS) were analyzed in the laboratory.

- **Nutrients**. Nutrient analysis included ammonia, nitrate, and phosphorous compounds, since nutrient have been reported at high concentrations in the watershed and are known biostimulants associated with agricultural operations and urban runoff.

- **Metals**. Metals analysis included the following, which are known to be associated with urban runoff and have some level of aquatic toxicity: cadmium, chromium, copper, lead, nickel, zinc, silver, arsenic, selenium and mercury.

- **Pesticides**. Testing was conducted for select organo-phosphorous, organo-chlorine, and carbonate pesticides, including some historic/persistent pesticides and pesticides currently in common usage in the strawberry and lettuce fields in the Watsonville area. Pesticide analyses were completed for all stations in the late summer sampling and the second two rainfall runoff sampling events. The first runoff event (in October) generated very little flow;

and pesticide analyses were only run on samples from station A44 at Beach Road. Analytical methods followed those developed and in use by the California Department of Food and Agriculture.

6.3 MONITORING RESULTS

Sampling Events

Four sampling events were carried out in the 1994 fall and early winter season. The first sampling event was in September at the end of the irrigation season. The other sampling events were conducted for three separate storms, one each in October, November and December 1994. **Table 6-3** provides a listing of the sampling dates, days since previous storm, storm duration and rainfall totals.

Also listed for reference in **Table 6-4** during the 1994-95 winter season are the sampling dates for monitoring work conducted by the PVWMA in the Watsonville Sloughs. The PVWMA monitoring was done as part of their on-going investigations of stream diversion - groundwater recharge alternatives. The PVWMA sampling was done at a limited number of sampling stations, most of which correspond with the sampling sites for the Watsonville Sloughs project; and the results are presented in this report for comparison and to expand the water quality information base.

Tables 6-5, 6-6 and **6-7** show, respectively, results obtained from Questa's sampling for metals, mineral/nutrient/physical parameters and pesticides. **Table 6-8** lists the pesticide sampling results obtained from the monitoring by PVWMA. Discussion of these various data tables follows.

Metals

The results of analyses for metals are listed by sampling station and sampling date in **Table 6-5,** with a listing of the corresponding water quality criteria (i.e., limits) for freshwater and salt water aquatic life at the end of the table. The "MDL" at the top of the table shows the analytical detection limit for each metal. Highlighted in bold-faced type are the sample results that exceed either the short-term (mc) or long-term (cc) water quality limit for either freshwater, salt water aquatic life, or both.

Inspection of these sampling data show no detection of mercury, selenium or silver, and show consistently low readings for cadmium, chromium, and arsenic. The four metals found at elevated concentrations, above water quality criteria, were copper, lead, zinc and nickel. A summary of the number of results (out of 30 total samples) exceeding water quality criteria for each of these constituents is as follows:

TABLE 6-3

SUMMARY OF SAMPLING EVENTS

Sampling Event	Sampling Date	Days Since Previous Storm	Storm Duration (Days)	Total Rainfall (in.)*
1	9/7 - 9/8/94	45	1	0
2	10/5/94	73	1	0.97
3	11/15/94	6	3	0.55
4	12/14/94	4	3	1.04

* Data obtained from the Fowle Reservoir Station in Freedom, CA (Watsonville Water Division, 1995).

TABLE 6-4

SUMMARY OF WATER QUALITY SAMPLING BY PVWMA FOR 1994-1995 WINTER SEASON

Sampling Date	Sampling Station			
	Harkins Slough Pump Station (HS)	San Andreas Road (A32)	Shell Road (A41)	Beach Road Ditch (A44)
10/18/94	m	m	m	
11/15/94	f	m		
12/8/94	m	m		
1/21/95	f	f	m	f
2/18/95	m	m	m	m
2/25/95		p*		
3/7/95	p*			
4/3/95	f*	f*	m	m

f = full analysis, including minerals, metals, and pesticides (per Questa)
m = minerals analysis only
p* = pesticides only (Questa screens plus organochlorine herbicide screen)
f* = "f" plus organochlorine herbicide screen.

TABLE 6-5

WATER QUALITY SAMPLING RESULTS FOR METALS

September 7 and 8, 1994

Station ID	ANALYTES									
	Cd	Cr	Cu	Pb	Zn	Ag	As	Se	Hg	Ni
MDL	1.0	2.0	5.0	5.0	1.0	1.0	2.0	2.0	0.5	2.0
A21	ND	ND	ND	ND	ND	ND	ND	ND	ND	**7.4**
A61	ND	8.0	**6.0**	ND	37	ND	5.0	ND	ND	**23**
A42	**11**	68	**290**	**490**	**1800**	ND	6.0	ND	ND	**220**
A34	ND	2.5	**5.5**	ND	20	ND	5.1	ND	ND	8.2
A32	ND	13	**24**	**10**	**100**	ND	4.5	ND	ND	**39**
A41	ND	3.5	**6.2**	ND	10	ND	3.4	ND	ND	**11**
A44	ND	3.0	ND	**7.1**	1.6	ND	4.3	ND	ND	**13**

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A61	ND	5.1	**16**	ND	**97**	ND	3.7	ND	ND	**16**
A34	ND	4.7	**10**	ND	51	ND	7.5	ND	ND	**8.9**
A42	ND	4.3	**15**	**17**	**260**	ND	4.1	ND	ND	**17**
A62	ND	3.3	**9.4**	ND	**170**	ND	ND	ND	ND	**42**

November 15, 1994

A62	ND	4.9	ND	ND	51	ND	2.8	ND	ND	**22**
A61	ND	2.8	**5.6**	ND	65	ND	2.2	ND	ND	**11**
A42	ND	2.2	**5.5**	ND	34	ND	2.6	ND	ND	4.7
A44	ND	12	**19**	**10**	47	ND	2.5	ND	ND	**29**
A41	ND	13	**20**	**9.4**	41	ND	4.1	ND	ND	**36**
A34	ND	5.4	**17**	**11**	**170**	ND	3.3	ND	ND	**8.5**
A32	ND	8.3	**21**	**7.8**	**130**	ND	4.2	ND	ND	**28**
A21	ND	5.0	**11**	**22**	47	ND	3.3	ND	ND	**23**
A13	ND	4.3	**11**	**5.8**	41	ND	ND	ND	ND	**17**

TABLE 6-6 (Cont'd)

WATER QUALITY SAMPLING RESULTS
FOR MINERAL, NUTRIENT AND PHYSICAL PARAMETERS

November 15, 1994

Station ID	TSS	TDS	Hardness	NH_3	pH	Oil & Grease	NO_3	PO_4
A62	ND	510	180	0.4	5.69	ND	1.9	0.13
A61	20	630	320	1.0	6.71	0.7	1.5	1.75
A42	8.0	320	75	0.2	7.35	0.7	15	4.05
A44	580	2500	880	ND	7.8	ND	8.9	1.21
A41	340	1800	760	0.4	7.96	ND	90	0.47
A34	140	220	100	0.4	7.54	1.1	12	0.87
A32	600	1700	510	0.5	7.85	ND	220	0.82
A21	330	1000	560	0.8	6.69	ND	270	0.48
A13	220	540	270	0.2	6.9	ND	44	0.77

December 14, 1994

Station ID	TSS	TDS	Hardness	NH_3	pH	Oil & Grease	NO_3	PO_4
A62	ND	210	80	0.2	6.6	ND	1.3	0.38
A61	ND	570	270	1.3	6.7	6.8	<1	6.3
A42	ND	240	74	0.1	6.9	1.3	1.2	1.3
A44	60	2700	790	ND	7.9	ND	315	3.3
A41	42	1500	660	0.3	7.7	ND	170	2.4
A34	16	460	160	0.3	7.2	ND	16.4	2.0
A32	210	1100	410	0.5	6.9	ND	13	0.45
A21	70	580	320	0.5	6.9	ND	13	0.45
A13	24	700	190	0.2	6.9	ND	17	0.56
A29	ND	340	140	0.3	7.0	ND	14	0.93

TABLE 6-7

WATER QUALITY SAMPLING RESULTS FOR PESTICIDES

September 7 and 8, 1994

Sampling Station	Organochlorine Screen	Organophosphate Screen	Carbamate Screen	Concentration ug/L	MDL ug/L	Water Quality Criteria (ug/L)
A21	ND	ND	ND	NA	NA	NA
A61	ND	ND	ND	NA	NA	NA
A42	ND	ND	ND	NA	NA	NA
A42	ND	ND	ND	NA	NA	NA
A34	ND	ND	ND	NA	NA	NA
A32	ND	ND	ND	NA	NA	NA
A44	ND	ND	ND	NA	NA	NA

October 5, 1994

Sampling Station	Organochlorine Screen	Organophosphate Screen	Carbamate Screen	Concentration ug/L	MDL ug/L	Water Quality Criteria (ug/L)*
A44	DDD			0.77	0.1	0.00083 (H.H.)
	DDE			0.95	0.04	0.00059 (H.H.)
	DDT			2.87	0.1	0.00059 (H.H.) 0.13 (salt, MC) 1.1 (Fresh, MC) 0.001 (CC)
	Dicloran (Botran)			0.67	0.1	NE
	Endosulfan Sulfate			1.52	0.04	0.93 (H.H.)
	Iprodione (Rovral)			3.53	0.1	NE
		Dimethoate (Cygon)		21.1	0.5	NE
			ND	NA	NA	NA

TABLE 6-5 (Cont'd)

WATER QUALITY SAMPLING RESULTS FOR METALS
December 14, 1994

Station ID	ANALYTES Cd	Cr	Cu	Pb	Zn	Ag	As	Se	Hg	Ni
MDL	1.0	2.0	5.0	5.0	1.0	1.0	2.0	2.0	0.5	2.0
A62	ND	2.1	ND	ND	23	ND	ND	ND	ND	**9.2**
A61	ND	ND	ND	ND	24	ND	ND	ND	ND	**8.5**
A42	ND	ND	ND	ND	21	ND	ND	ND	ND	3.4
A44	ND	4.5	**17**	ND	14	ND	2.9	ND	ND	**19**
A41	ND	2.7	**5.4**	ND	19	ND	2.7	ND	ND	**15**
A34	ND	ND	ND	ND	30	ND	ND	ND	ND	5.5
A32	ND	4.0	**7.7**	ND	48	ND	4.2	ND	ND	**17**
A21	ND	2.3	ND	**6.5**	23	ND	4.7	ND	ND	**16**
A13	ND	2.8	**5.5**	ND	23	ND	4.5	ND	ND	**13**
A29	ND	ND	ND	ND	19	ND	ND	ND	ND	7.7

Results in parts per billion (ppb)
ND: Not Detected
MDL: Minimum Detection Limit
* Due to limited rainfall and resulting runoff, only samples in upper watershed were analyzed.

Benefical Use	WATER QUALITY CRITERIA (ug/l) Cd	Cr	Cu	Pb	Zn	Ag	As	Se	Hg	Ni
Fresh Water Aquatic										
MC	3.9	1700	18	82	120	4.1	360	20	2.4	1400
CC	1.1	210	12	3.2	110	-	190	5	0.012	160
Salt Water Aquatic										
MC	43	-	2.9	220	95	2.3	69	300	2.1	75
CC	9.3	-	2.9	8.5	86	-	36	71	0.025	8.3
Drinking Water	10	50	1,000	50	5,000	50	50	10	2.0	-

MC - **Maximum Concentration**. The highest concentration of a pollutant to which aquatic life can be exposed for a short period of time (one hour average) without deleterious effects.

CC - **Continuous Concentration**. The highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (four days) without deleterious effects.

TABLE 6-6

WATER QUALITY SAMPLING RESULTS FOR MINERAL, NUTRIENT AND PHYSICAL PARAMETERS[1]

September 7 and 8, 1994

Station ID	TSS	TDS	Hardness	NH_3	pH	Oil & Grease	NO_3	PO_4
A41	66	1800	780	0.1	NA	ND	158	1.1
A61	1300	1100	840	1.2	NA	5.3	1.5	9.4
A34	25	800	580	ND	NA	ND	66	1.0
A42	920	1000	710	2.1	NA	0.7	23	5.6
A44	82	680	390	0.5	NA	ND	<1	1.5
A32	720	1200	630	0.3	NA	ND	36	5.1
A21	7	1800	790	ND	NA	ND	286	<0.1

October 5, 1995

Station ID	TSS	TDS	Hardness	NH_3	pH	Oil & Grease	NO_3	PO_4
A61	NA	NA	250	NA	6.8	1.2	NA	NA
A34	NA	NA	320	NA	7.5	ND	NA	NA
A42	NA	NA	270	NA	6.7	1.1	NA	NA
A62	NA	NA	310	NA	5.3	ND	NA	NA
A41	NA	NA	*	NA	8.3	*	NA	NA
A44	NA	NA	*	NA	7.5	*	NA	NA
A32	NA	NA	*	NA	6.7	*	NA	NA

1. Applicable Drinking Water Standards:

- TDS - 500 mg/l, recommended
  1,000 mg/l, upper limit
- NO_3 - 45 mg/l, maximum

TABLE 6-7 (Cont'd)

WATER QUALITY SAMPLING RESULTS FOR PESTICIDES

November 15, 1994

Sample ID	Organochlorine Screen	Organophosphate Screen	Carbamate Screen	Concentration ug/L	MDL ug/L	Water Quality Criteria (ug/L)*
A13	Dacthal (Chlorthal)			0.38	0.04	14,300
	Oxyfluorfen (Goal)			1.89	0.04	NE
A21	Iprodione (Rovral)			1.07	0.1	NE
		ND	ND	NA	NA	NA
A62	ND	ND	ND	NA	NA	NA
A61	ND	ND	ND	NA	NA	NA
A42	ND	ND	ND	NA	NA	NA
A34	Dacthal (Chlorthal)			0.40	0.04	14,300
	DDE			0.18	0.04	0.00059
	DDT			0.42	0.1	0.00059 (H.H.) 0.13 (salt, MC) 1.1 (Fresh, MC) 0.001 (CC)
	Iprodione (Rovral)			3.08	0.1	NE
		Diazinon		1.33	0.05	0.009
		Movinphos (Phosdrin)		0.59	0.5	NE
			ND	NA	NA	NA
A32	DDE			0.36	0.04	NE
		ND	ND	NA	NA	NA
A41	ND	ND	ND	NA	NA	NA
A44	Dacthal (Chlorthal)			0.38	0.04	14,300
	Oxyfluorfen (Goal)			1.89	0.04	NE
		ND	ND	NA	NA	NA

TABLE 6-7 (Cont'd)

WATER QUALITY SAMPLING RESULTS FOR PESTICIDES

December 14 1994

Sampling Station	Organochlorine Screen	Organophosphate Screen	Carbamate Screen	Concentration ug/L	MDL ug/L	Water Quality Critera (ug/L)
A13	ND	ND	ND	NA	NA	NA
A29	ND	ND	ND	NA	NA	NA
A32	ND	ND	ND	NA	NA	NA
A41	ND	ND	ND	NA	NA	NA
A44	Oxyfluorfen (Goal)			0.43	0.04	NE
		ND	ND	NA	NA	NA

ND - Not Detected
NA - Not Applicable
NE - Not established.
MDL - Minimum Detection Limit
*Source - Central California Regional Water Quality Control Board, EPA Recommended Maximum Levels in fresh water.
H.H. - Human health criterion.
Salt, M.C. - Saltwater aquatic life criterion, maximum.
Fresh, M.C. - Freshwater aquatic life criterion, maximum.
C.C. - Continuous concentration criterion, saltwater and freshwater.

TABLE 6-8

PESTICIDE RESULTS FROM PVWMA SAMPLING

Sampling Station	Sampling Date	Pesticides Concentrations Detected
HS	11/15/94 1/21/95 3/7/95 4/3/94	ND Dieldrin* - 0.096 ppb ND ND
A32	1/21/94 2/25/95 4/3/94	Dacthal - 0.056 ppb Dieldrin* - 0.040 ppb DDE - 0.18 ppb (raw water) DDE - 0.08 ppb (filtered water) ND
A44	1/21/95	Dacthal - 0.41 ppb Dieldrin* - 0.07 ppb DDT - 0.13 ppb

ND - No pesticides detected
* May be DDE rather than Dieldrin

Metal	Salt Water Criteria CC	MC	Freshwater Criteria CC	MC
Copper	21	21	9	5
Lead	7	1	9	5
Zinc	7	7	5	5
Nickel	24	1	1	0

CC - Continuous Concentration; MC - Maximum Concentration

From these data it is clear that both aquatic organisms in the freshwater portion of the slough system as well as downstream in the estuarine reach are potentially at risk from the presence of these four heavy metals. With respect to geographic distribution, exceedance of the water quality criteria were found at every sampling station except A29-Larkin Valley, which was only sampled once. Elevated copper and nickel concentrations were found at all sampling stations. Elevated levels of lead were found at all stations except on Struve Slough (Stations A61 and A62). Zinc was not found at elevated levels in Harkins Slough (A21), Gallighan Slough (A13) or at Shell Road (A41).

Over the course of the four sampling events the concentrations of all metals generally declined, from peak levels in September to minimum values in the December sampling. This is most probably attributable to the dilution effect from storm runoff. Even so, copper and nickel concentrations detected during the December sampling event at several stations remained above at several stations the water quality criteria limits for salt water aquatic species, which are the most sensitive with respect to these metals.

Mineral, Nutrient and Physical Parameters

Results of analyses for various mineral, nutrient and physical water quality parameters are listed in **Table 6-6**, and summarized as follows:

- **Total Suspended Solids (TSS)**. Results for TSS showed wide-ranging concentrations, from non-detectable to 1,300 mg/l. Generally, the readings were in the range of 20 to 600 mg/l, which corresponds closely to the reported historic data. The concentrations were highest during the November runoff event and lower in December; this may have been due to the timing of sampling during the storm or the effect of dilution. The urban stations (A61, A62, A42 and A34) were all substantially lower during the December sampling due, presumably, to prior wash-off of sediments and other materials from these areas. It should be noted that the three highest TSS readings were in September, during a non-runoff period. Water levels were extremely low at several sampling stations in September and these results are attributable to apparent suspension of bottom sediments which occurred in the process of obtaining samples from shallow water areas. This disturbance of sediments may have contributed to the high metals concentrations observed in the September sampling, particularly at Station A42.

- **Total Dissolved Solids (TDS) and Hardness**. The TDS results showed concentrations in the range of about 200 to 1,000 mg/l in the upper, freshwater sections of the sloughs, increasing to as high 1,800 to 2,700 mg/l, respectively, at Shell Road and Beach Road Ditch, where tidal influence occurs. Notably higher concentrations of TDS were observed during the September sampling at the upstream sampling stations; this may be attributable to the effect of irrigation drainage-return flows into the sloughs at this time of year along with the concentrating effect of evaporation in shallow water areas. The TDS concentrations were lowest at stations most influenced by urban runoff (e.g., A34, A42, A61, A62 and A29) during the November and December samplings. Water hardness readings showed similar trends as the TDS results: that is, increasing from upstream to downstream locations and declining substantially in response to the fall and early winter runoff.

- **pH**. The pH readings ranged from a low of 5.69 at Station A62, to a high of 8.3 at Station A41. Generally, the pH was in the acceptable range (for aquatic habitat) of 6.0 to 9.0 at all stations. The exceptions were measured at A62 (Struve Slough), where two low readings of 5.3 and 5.69 were recorded in September and November, respectively. The pH was 6.6 at this station during the December sampling. The reason for the two abnormally low readings was not determined; no other exceptional water quality readings (e.g., related to metals, ammonia, etc.) occured at this station during these sampling times.

- **Oil and Grease**. Oil and grease were nondetectable with the exception of samples taken from the urban area stations (i.e., A61, A42 and A34). At these stations the oil and grease concentrations ranged from 0.7 to 6.8 mg/l. The highest readings were consistently at Station A61 (Struve Slough) which is located downstream at Highway 1. The high readings of 5.3 and 6.8 mg/l are high enough to be of concern locally in this part of the slough system; however, the effects do not appear to extend very far downstream, due to a combination of wetland filtering and dilution.

- **Ammonia**. Ammonia concentrations in the range of 0.1 to more than 1.0 mg/l were observed throughout the slough system during all sampling events. The only samplings where ammonia was nondetectable were during November and December at Beach Road (A44) and once each at upper Watsonville Slough (A34) and Harkins Slough (A21); the latter two results were during the September sampling. The highest ammonia readings were consistently recorded at the A61 sampling station on Struve Slough. All three readings (September, November and December) were 1.0 mg/l or more, which is abnormal and is of concern from an aquatic toxicity standpoint. Generally, all other stations reported concentrations of 0.5 mg/l or less, with the exception of a reading of 2.1 mg/l at station A42 (upper Watsonville Slough) in September and 0.8 mg/lg at A21 (Harkins Slough) in November. There was no observed correspondence between the ammonia concentrations and the nitrate readings (see below).

- **Nutrients**. Nitrate and phosphate are essential nutrients for aquatic plants; and high concentrations can stimulate and accelerate algae production to nuisance levels, depending upon other factors such as water temperature, sunlight, substrate, etc. Also, nitrate is a hazard to public health when occurring at concentrations of 45 mg/l or more in drinking water supplies.

The nitrate and phosphate data in **Table 6-6** show an extremely wide range of results for the slough system. The nitrate readings varied from less than 1 (i.e., nondectable) to 315 mg/l; and both of these results occured at the Beach Road Ditch sampling point (A44) at different times. The lowest reading occurred in September and the highest in December, likely a result of nitrates flushing from the agricultural soils and drains. The overall lowest nitrate readings were found at the lower Struve Slough sampling station (A61), where the readings were 1.5, 1.5 and less than 1.0 mg/l for the three sampling times. As noted earlier, this is the same station where ammonia readings were consistently the highest (greater than 1.0 mg/l); this is unusual. One possible explanation for this is that there is very little watershed nitrate contribution to Struve Slough (Station A62 also showed low nitrate readings of 1.9 and 1.3 mg/l), and that the wetlands are an efficient nitrogen sink where denitrification rates are able to keep pace with nitrate inputs. The high ammonia readings may possibly be related to direct inputs of ammonia (e.g., from wildlife, water fowl, or livestock) or respiratory reduction of nitrate to ammonia. In any event, the data clearly show Struve Slough to have an ammonia problem which is unrelated to nitrate concentrations.

The highest nitrate readings were found at sampling stations downstream of irrigated agricultural fields, namely Beach Road Ditch (A44), Shell Road (A41), San Andreas Road (A32) and Harkins Slough (A21). All of these stations recorded nitrate concentrations in excess of 150 mg/l at one sampling time or another. Nitrate readings for the other sampling stations at Gallighan Slough (A13), Larkin Valley (A29) and Upper Watsonville Slough (A34 and A42) were below 25 mg/l, with the exception of a 44 mg/l reading at Gallighan Slough in November, and 66 mg/l at Watsonville Slough (A34) in September.

Phosphate sampling results showed different trends than the nitrate data. The highest phosphate readings were at the urban area sampling stations on Struve Slough and Upper Watsonville Slough; they did not coincide with high nitrate concentrations. The phosphate readings at these stations ranged as high as 6.3 and 9.4 mg/l at A61, and 4.0 and 5.6 mg/l at A42; these occured during non-runoff and runoff sampling periods. The phosphate readings for the agricultural drainage areas were generally less than 1.5 mg/l, with the exception of values of 2.4 and 3.3 at Shell Road (A41) and Beach Road (A44), respectively, during the December runoff event. The recorded phosphate levels are more than ample for algae production; but, they have not other known water quality impact.

- **Pesticides**. The results of pesticide analyses listed in **Table 6-7** show no detectable concentrations in the water during the September dry season sampling, followed by a significant number of detections in October (at Beach Road Ditch) and November, and then declining detections in December. The PVWMA sampling results (see **Table 6-8**) through the rest of the winter runoff season showed additional detection of a limited number of pesticide compounds (mainly DDT, DDE and Dacthal) during January and February, with no further detections in March and April samplings.

As would be anticipated, the detection of pesticides occured most frequently at the stations influenced by runoff or return flow from agricultural fields, namely Beach Road Ditch (A44), Watsonville Slough (A32 and A34), Harkins Slough (A21) and Galligan Slough (A13). No pesticides were detected at the upstream urban/residential sampling stations (A61, A62, A42 and A29). Interestingly, there was also no detection of pesticides at the Shell Road Pump Station, the most downstream sampling point on Watsonville Slough.

With respect to the specific compounds found, DDT and its derivatives DDE and DDD were most prominent, along with repeat occurrences of Dacthal, Iprodione, Oxyflurofen; all of these compounds are organochlorines which have the greatest longevity in the environment. DDT has not been in use for many years; but the other pesticides are currently used agriculturally within the watershed. No carbamate pesticides were detected in any samples and there were only single detections of three or organophosphates-dimethoate, diazinon, and movinphos.

Water quality criteria for the pesticides detected have only been established for DDT/DDE, dacthal, endosulfan and diazinon. The detected concentrations for endosulfan and diazinon exceeded the freshwater and salt water aquatic protection criteria for these compounds; also all eight of the DDT/DDE concentrations (including PVWMA sample results) were above the established "average" concentration limit; but only one exceeded the freshwater maximum limit. All other detected pesticides were below established water quality criteria, or no criteria have been established.

Quality Control

Results of quality control samples were reviewed during the course of the sampling program to verify the adequacy of field and laboratory methods. Generally the blank, split and duplicate samples showed close conformance with the reported results; however, there were some exceptions noted. These were believed to be caused by the influence of suspended sediment on various constituent concentrations. Many constituents, particularly metals, adhere to sediments and particulate matter, such that variations in sediment concentration or simply different sediments (from one sample to another) can be responsible for different analytical results. Also, due to the very low detection and reporting concentrations (i.e., parts per billion), differences in results may seem large on a relative (i.e., percentage scale), while being small to insignificant in absolute terms (i.e., in parts per billion). Overall, the quality control results show the monitoring data to be valid, consistent with historic data and supportive of the conclusions reached by this study.

6.4 WATER QUALITY SUMMARY

Following is a discussion of the water quality monitoring data obtained from this investigation and a comparison with historic findings. It should also be recognized that the water quality results in this study are subject to the inherent limitations of instantaneous runoff sampling (e.g., the extreme variability of water quality concentrations during storm events).

General Physical Parameters

Field and laboratory measurements for temperature, pH, DO, EC and turbidity showed results consistent with historical data for the Watsonville Slough System. There were no remarkable measurements; and the data generally reflect adequate conditions required for warm water fisheries. As previously noted in the text, the current sampling showed two pH readings below 6.0 (5.3 and 5.69) at the upper Struve Slough sampling station (A62).

Nutrients

Two nutrients, phosphate and nitrate, were found at high concentrations, consistent with historical results. Phosphate readings were generally in the range of 0.5 to 5.0 mg/l, with a few higher values. The highest readings were at stations representative of urban runoff (A42 and A61), and at the Beach Road Ditch (A44). Phosphate readings were generally highest in the September (dry season) sampling; but high readings at some of the individual sampling stations were also noted for the November and December runoff events.

Nitrate readings were typically in the range of 10 mg/l to more than 200 mg/l (as NO_3) for each sampling period. The high readings appeared more frequently and were more widespread than indicated by historic data. The notable exception was Struve Slough (Stations 61 and 62) which had consistently low nitrate readings of less than 2.0 mg/l at all sampling times. The high nutrient concentrations were not accompanied by depressed DO levels or noticeable algae; thus, it appears that turbidity, temperature, substrate conditions or other factors (and not the abundant supply of nutrients) control the growth of algae in the slough system. It is also possible that algae growth may be a seasonal (e.g., spring, early summer) occurrence that does not coincide with the fall-winter sampling program for this study.

The most significant finding of the nitrate water quality data is the great variation in concentrations from Struve Slough (where nitrate is essentially absent), to the extremely elevated levels downstream of the irrigated agricultural fields. However, no definitive impact on beneficial uses can be determined from these nitrate levels, since the water in the sloughs does not presently serve as a source of drinking water, and extensive widespread algae growth and depressed DO levels has not been observed. Further investigation is needed to determine the seasonality and significance of the nutrient-algae relationships in the slough system and to gain a better understanding of the uncharacteristically low nitrate readings from Struve Slough.

Ammonia

Ammonia readings in the 0.1 to 0.5 mg/l range were observed throughout the sloughs, similar to historic data; these are above the generally accepted chronic toxicity levels for fish (0.02 mg/l as NH_3). However, the toxicity in a given water body varies based on other factors and the tolerances of local aquatic species. The highest ammonia readings were in Struve Slough (Station A61) and upper Watsonville Slough (Station 42); these exceeded 1.0 mg/l which are clearly cause for concern for aquatic organisms. From these data, it is clear that ammonia is common and persistent in the sloughs; but the source is not clearly evident. It is possible that the wildlife and waterfowl within the slough system contribute ammonia (through waste products) sufficient to explain many of the observed readings. Leaching and runoff from manure stockpiles and leakage from industrial sites (e.g., refrigerants) are other possible sources. These potential sources are more likely to explain the several high (greater than 1.0 mg/l) readings for Struve Slough (A61) and the Upper Watsonville Slough station (A42). There is also the possibility that respiratory reduction of nitrate to ammonia (along with denitrification) may be occurring in Struve Slough or other locations in the system. The data collected from this study are consistent with historical findings that show potential ammonia toxicity problems. The source(s) cannot be specifically identified; future study efforts should be focused on Struve Slough.

Pesticides

The sample results for September yielded no evidence of pesticides in the water column at any of the stations, consistent with historical data for the water column. However, during runoff events pesticides were found at several sampling stations - primarily in locations bordering and downstream of agricultural areas. Pesticides detected included DDT and its derivatives, which are no longer in use; plus several currently used pesticides. **Table 6-9** summarizes the pesticides detected, along with the corresponding locations and cross-reference to the various types of crops for which the particular pesticide is known to be used. The sampling data show clear evidence that pesticides from past and current agricultural practices are closely associated with sediments in the sloughs, as they tend to occur more widely and peak with erosion-producing runoff events. The preponderance of pesticides were detected in the November and December sampling events.

Historically, the most significant finding of water quality impairment in the slough system has been the evidence of pesticide accumulation in fish and shellfish tissue. Of the pesticides found in the tissue samples, DDT (and derivatives), dacthal, and possibly, dieldrin were also detected in the water quality monitoring for this project and by PVWMA. Other pesticides detected in tissue samples, e.g., endrin and toxaphene, were not found in any of the water quality samples. Because of the persistence of the various pesticide compound found in tissues (all of which are organochlorines), they are likely to remain in the slough sediments or on the agricultural fields for long periods of time. Since all detected pesticides in tissue samples, except dacthal and endosulfan, are no longer in use, their detection in water quality samples must be attributable to suspension of slough sediments or erosion from farm fields where they were used in the past. This study did not identify the specific sources of these pesticides, beyond the general conclusion that they are derived from either present or past runoff and erosion from agricultural fields. Their continued detection in fish and shellfish tissue (as recently as 1993) is evidence of a remaining water quality impairment of the Watsonville Slough System.

Heavy Metals

Copper, especially, as well as nickel, lead and zinc were found at concentrations in the sloughs that are of concern for freshwater aquatic organisms. Copper was routinely found to exceed criteria for freshwater and salt water species. Lead and zinc also had numerous values above the applicable water quality limits. Nickel, while routinely detected, was generally at acceptable concentrations for freshwater aquatic habitat, but in excess of water quality criteria for saltwater species. All of these constituents are typically associated with urban runoff; but, while some of the highest reading were at the urban runoff sampling stations (e.g., A42), occurrence of these metals was not restricted to these locations. All sampling stations, from urban and agricultural areas alike, with the exception of the Larkin Valley site (A29), showed multiple instances of heavy metals concentrations in excess of water quality criteria. Thus, a specific source or land use activity cannot be identified as the cause.

A notable aspect of the sampling results was the significant decline in the concentration of heavy metals in response to the early season runoff events. The most noticeable change with time was at station A42, representative of runoff from the Watsonville urban area.

The present data for heavy metals are more complete than the historic data. They show evidence of potential acute and chronic toxicity problems by virtue of the exceedance of established water quality criteria for aquatic life, for both freshwater and salt water. Whether or not the observed concentrations are exerting toxic effects on the aquatic species is unknown; and the system should be investigated further. It is possible that some of this can be accomplished or coordinated with the current UCSC toxicity studies to determine the significance of heavy metals concentrations on the specific aquatic organisms in the slough system.

Oil and Grease

Detectable concentrations of oil and grease are found in the areas of the sloughs near Highway 1 and the City of Watsonville. At the levels reported a sheen may be visible under certain conditions. However, no exceedances of water quality standards (visible oil sheen) were noted during this study. Street runoff containing motor oil residue is the logical explanation for this. Elsewhere in the sloughs the oil and grease is nondetectable due to limited sources, dilution and the effectiveness of wetland vegetation as a filtering mechanism.

There is no established numerical limit for oil and grease in surface waters. The standard contained in the Regional Board's Basin Plan is a narrative objective which states that:

> "Waters shall not contain oil, greases, waxes or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses."

The higher concentrations observed in the study (e.g., 5 and 6 mg/l) are sufficient to create a visible oil sheen and, thus, would be considered in excess of the water quality standard. Adverse effects on aquatic organisms can occur at oil and grease concentrations of less than 1.0 mg/l if the oil is of petroleum origin, as opposed to natural animal or vegetable oil sources. In general, the "nondetectable" oil and grease readings for the slough system indicate suitable water quality conditions; but, the locations consistently showing measurable levels of oil and grease represent potential problems that warrant continued vigilance in the urban drainage areas tributary to these parts of the slough.

TABLE 6-9

PESTICIDE DETECTED RELATED TO CROP TYPE

Detected Pesticide	Sampling Station Detected	Crop Type															
		Strawberries	Flowers	Apricots	Celery	Head Lettuce	Leaf Lettuce	Cauliflower	Kohlrabi	Broccoli	Spinach	Artichokes	Turnips	Collards	Beans	Beets	Gardens
DDT*	A44, A34																
DDE*	A44, A34, A32																
DDD*	A44																
Dicloran (Botran)	A44				X												
Endosulfan Sulfate	A44																
Iprodione (Rovral)	A44, A34, A21, A13	X	X	X		X	X	X									X
Dimethoate (Cygon)	A44		X			X	X	X		X	X						
Dacthal (Chlorthal)	A44, A34, A32		X					X	X	X			X	X			X
Oxyfluorfen (Goal)	A44											X					X
Diazinon	A34	X	X		X	X	X			X			X	X	X	X	X
Mevinphos (Phosdrin)	A34	X			X	X	X	X		X	X	X					
Vinclozolin (Ronilan)	A13	X	X			X											
Dieldrin*	A44, A32																

* Banned pesticides, no longer in use.

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Litter and Debris

Urban litter and debris accumulate in various locations of the sloughs due to runoff from city streets, as well as direct, illicit littering and dumping in roadside ditches and the sloughs themselves. The accumulated debris is unsightly, can contribute to the obstruction of culverts and can possible introduce hazardous chemicals or other deleterious substances to the water. No specific sampling was conducted for litter and debris; but observations during water quality sampled noted significant accumulation of litter, particularly at road crossings on Harkins Slough and Struve Slough.

Water Flow and Circulation

The sloughs contain extensive areas of stagnant and slow moving water due to the flat gradient and additional obstructions to flow caused by road crossing, blocked culverts and sediment build-up. The urban development in the watershed, with associated streets, storms drains and other impervious surfaces has altered the hydrology by increasing winter runoff peaks and reducing groundwater recharge and spring/summer base flow contribution. However, this is offset to a degree by the percolation and return flow from irrigation or agricultural lands. Shallow, slow-moving and stagnant water conditions were noted during water quality sampling and other watershed field studies; but no specific testing was done to document and correlate these conditions with water quality parameters such as DO and temperature. This should be done in the future to assess the significance of stagnant water areas on the overall slough system water quality.

Drinking Water Suitability

Drinking water standards differ substantially from criteria for aquatic organisms. Generally, drinking criteria are more lenient for minerals and metals (see **Tables 6-5** and **6-6**) and more stringent for pesticides (see **Table 6-7**). The results of the water column analyses give rise to three main areas of potential concern: nitrates, coliform bacteria and pesticides. The proposed PVWMA groundwater recharge project is presently the only envisioned beneficial use for which drinking standards would be relevant. If implemented, this project would chlorinate and filter water diverted from the slough system before delivering it to spreading basins for recharge. This treatment process should remove coliform bacteria and pesticides, but it would not reduce nitrate levels significantly. Therefore, the observed high nitrate readings represent a potentially significant problem to be considered in the timing and location of water diversions for this proposed project.

SECTION 7

WATER QUALITY MANAGEMENT ALTERNATIVES

This section describes and reviews the range of potential management measures available for improvement of water quality conditions and wetland restoration within the Watsonville Slough System. The analysis and review of alternative management practices in this section provides the basis for the recommended management measures and follow-up studies which are presented in **Section 8**.

7.1 SOURCES OF WATER QUALITY PROBLEMS

Section 6 summarized the historical water quality findings and the results of the water quality monitoring completed as part of this project. From the evidence, eight basic water quality problems, which are summarized below, are related in a matrix format to potential contributing watershed sources in **Table 7-1**. The field studies conducted under this project were not directed at locating and documenting site-specific pollutant sources in the watershed. Therefore, the information presented here must be understood to represent our best estimates, based upon: (1) the present and historic data; (2) known watershed activities; and, (3) literature findings relative to urban, rural and agricultural non-point source pollution. **Table 7-1** lists a broad range of land and water management activities or factors which are specific to the Watsonville Sloughs and indicates which factors are likely or known contributors to specific water quality problems.

Sedimentation

Sedimentation in the sloughs due to soil erosion is a major water quality problem. The sediments deposited in the slough channels obstruct and alter normal drainage patterns, reduce water clarity, blanket vegetation and aquatic organisms, and transport attached nutrients and pesticides into the receiving waters. Pesticide accumulation in fish and shellfish tissues are the basis for the designation of Watsonville Slough as an impaired water body. Agricultural lands are the primary source of soil erosion; but erosion also occurs in connection with urban and rural development, as well as naturally, due to the high erodibility of the sandy soils in the watershed. However, erosion rates associated with land development and agricultural operations greatly exceeds that from natural landscapes, unless very strict erosion control practices are followed.

Nutrients

Two nutrients, nitrate and phosphate, are found in Watsonville Slough System at high concentrations. These nutrients can contribute to increased algal growth with consequent impairment of water quality for other organisms and from an aesthetic standpoint. It appears, from the lack of extensive algae

TABLE 7-1

CONTRIBUTING SOURCES OF WATER QUALITY PROBLEMS
KNOWN AND POTENTIAL TO WATSONVILLE SLOUGHS

CONTRIBUTING WATER/LAND MANAGEMENT FACTORS	WATER QUALITY PROBLEM							
	Sedimentation	Nutrients	Ammonia	Pesticides	Heavy Metals	Oil & Grease	Debris	Water Flow/Circulation
HILLSIDE AGRICULTURE								
• Tillage	x	x	-	x	-	-	-	-
• Access Roads	x	x	-	x	-	-	-	-
• Fertilizers	-	x	-	-	-	-	-	-
• Pesticides	-	-	-	x	-	-	-	-
• Irrigation	x	x	-	x	-	-	-	x[1]
• Groundwater Pumping	-	-	-	-	-	-	-	-
VALLEY FLOOR AGRICULTURE								
• Tillage	x	x	-	x	-	-	-	-
• Access Roads	x	x	-	x	-	-	-	-
• Fertilizers	-	x	-	-	-	-	-	-
• Pesticides	-	-	-	x	-	-	-	-
• Irrigation	x	x	-	x	-	-	-	x[1]
• Groundwater Pumping	-	-	-	-	-	-	-	-
• Tile Drains	-	x	-	x	-	-	-	x[1]
RURAL RESIDENTIAL								
• Septic Systems	-	x	-	-	-	-	-	-
• Roads	x	-	-	-	x	x	-	x
• Livestock	x	x	x	-	-	-	-	-
• Household Chemicals	-	x	x	x	x	x	-	-
• Groundwater Pumping	-	-	-	-	-	-	-	-
URBAN AREAS								
• Sanitary Sewer Leaks/Bypass	-	x	x	-	x	x	x	-
• Household Chemicals	-	x	x	x	x	x	x	-
• Motor Vehicles	-	-	-	-	x	x	-	-
• Street Surfaces	-	-	-	-	x	x	-	x
• Yard Litter and Landscaping	-	x	-	x	-	-	x	-
• Service Stations	-	-	-	-	-	x	-	-
• Commercial/Industrial Sites	-	x	x	x	x	x	x	-
• Impervious Surfaces	x	x	-	-	x	x	-	x
• Storm Drains			-	x	x	x	x	x
• General Litter & Debris	-	-	-	-	-	-	x	-
OTHER LAND USE ACTIVITIES								
• Illicit Dumping	x	x	x	x	x	x	x	x
• Isolated Industrial	-	x	x	x	x	x	x	-
• Highway 1	-	-	-	-	x	x	x	-
• **Landfills**		x	-	x	x	-	x	-
• Livestock Operations	x	x	x	-	-	-	-	-
FLOOD CONTROL								
• Pump Operations	-	-	-	-	-	-	-	x[1]
• Dredging/Channel Maintenance	-	x	-	x	x	-	-	-
WATER SUPPLY								
• Groundwater Pumping	-	-	-	-	-	-	-	-
• Proposed ARS Project	-	-	-	-	-	-	-	x
NATURAL SOURCES	x	x	x	-	-	-	-	x

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1 Positive effect on water flow in sloughs; adverse downstream effect in Pajaro River Estuary

problems in the sloughs, that turbidity, inappropriate substrate, temperature or other conditions, rather than nutrients, may presently be the limiting factor. The water quality data indicate the sloughs to be rich in nutrients, due primarily to agricultural fertilizer use; but nutrients are also derived from natural sources in the sloughs (e.g., plant decay, wildlife and waterfowl), urban runoff (i.e., fertilizer used in landscaping), livestock and, to a small extent, septic systems. There is a great difference in nitrate levels in portions of the sloughs receiving agricultural runoff (high) as compared with the other areas (low).

Ammonia

Ammonia levels in most of the sloughs generally exceed recommended limits for sensitive aquatic species; but the levels are not unusually high for wetland water bodies where there may be large waste contributions from wildlife and waterfowl populations. Microbial conversion of nitrate to ammonia (via respiratory reduction) is another possible source (NAS, 1978). Natural sources may be the cause of the high ammonia readings in Watsonville Sloughs; but additional sources may also include leaching from livestock areas or manure stockpiles, from sewer or septic system bypasses/leaks and possibly releases of ammonia products in commercial, industrial or residential areas. Consistently higher and alarming levels of ammonia have been documented in Struve Slough at Lee Road. Sources other than natural sources must be suspected at this location, but nothing specific has been documented thusfar.

Pesticides

Pesticides, including current as well as historically used compounds (i.e., DDT and DDE), have been occasionally detected in water quality sampling of the sloughs, particularly during runoff periods. When detected, most of the readings have been in excess of water quality criteria for these pesticide compounds. The most significant evidence of water quality impairment in the slough system is the accumulation of extremely high levels of pesticides in fish and shellfish tissue samples. Agricultural pesticide use is the main source. Runoff from urban sources may also contribute small quantities of pesticides to the sloughs from landscaping uses; but sampling to date has not shown this to be a source. Pesticides attached to soil particles are transported to the sloughs through erosion. The transported pesticides may be those in current use or former pesticides that still remain attached to soil particles.

Heavy Metals

Copper, nickel, lead and zinc are the principal metals found consistently throughout the sloughs at levels in excess of criteria for freshwater aquatic species. These constituents are characteristically the primary heavy metals found in urban runoff; but sampling in the sloughs show them to occur in both urban and agricultural drainage areas. Copper compounds used in connection with farming activities or at specific industrial sites are possible contributors. The County and City landfills are potential sources of heavy metals (via leachate); but, there is no evidence that they are a current source of heavy metals to the sloughs and both landfills have leachate control programs as well as on-going monitoring requirements.

Oil and Grease

Measurable concentrations of oil and grease are found in the areas of the sloughs near Highway 1 and the City of Watsonville. Motor oil leaks, exhaust and spills are the principal sources of oil and grease at these locations. Elsewhere in the sloughs oil and grease is nondectectable due to limited sources and the effectiveness of wetland vegetation as a filtering mechanism.

Litter and Debris

Urban litter and debris accumulate in various locations of the sloughs due to runoff from city streets, as well as direct, illicit littering and dumping in roadside ditches and the sloughs themselves. The accumulated debris is unsightly, can contribute to the obstruction of culverts, and possibly introduce hazardous chemicals or other deleterious substances to the water.

Water Flow and Circulation

The sloughs contain extensive areas of stagnant and slow moving water due to the flat gradient and additional obstructions to flow caused by road crossing, blocked culverts and sediment build-up. The urban development in the watershed, with associated streets, storm drains and other impervious surfaces has altered the hydrology by increasing winter runoff peaks and reducing groundwater recharge and spring/summer base flow contribution. However, this is off-set to some degree by the percolation and return flow from irrigation of agricultural lands. Water quality study of isolated stagnant water areas has not been completed to verify the extent of this problem.

7.2 ALTERNATIVE BEST MANAGEMENT PRACTICES

Based on the identified water quality problems and watershed conditions and activities, a broad range of potential Best Management Practices (BMPs) were identified. BMPs are defined as any program, technology, process, siting criteria, operating method, or device which controls, prevents, removes or reduces pollution (SWRCB, 1993). For the purposes of this project, BMPs are separated into two categories: (1) source control measures; and, (2) downstream treatment measures. Source control refers to specific measures that can be taken at specific locations and in the watershed area to remove or minimize pollutants at their source. Downstream treatment refers to physical measures to improve water quality or removal of pollutants within the slough system. The end of this section also includes a description of measures specifically for the enhancement and protection of wetlands and other biological resources in the slough system. It should be noted that many of the following urban, agricultural, and rural residential source control BMPs are already being used, as are some of the following downstream treatment measures. Listing of the identified BMPs and their applicability to specific water quality problems are provided in **Tables 7-2** and **7-3.** In **Table 7-3**, the estimated effectiveness of the various downstream treatment measure alternatives is rated. Following is a brief description of each of the BMPs. Further information on these measures is found in EPA's G guidance document cited in Appendix B, Part IVB1. This document also has information about the costs and effectiveness of various control measures.

The relative ratings in **Table 7-3** are based upon the professional judgement of the consultant, considering available literature and applicability of the treatment measure to the conditions presented by the Watsonville Slough System. Of particular note are the following cases where a measure is rated as having a "high degree of effectiveness".

- Wet detention/sedimentation basins are effective for control of sedimentation by the very nature and design of this measure.
- Drainage modifications and flow augmentation have the greatest potential to improve the flow and circulation of water in the system.
- Channel dredging is presently employed to control or respond to sedimentation problems in the system.
- Slough/tailwater circulation would be highly effective in addressing nutrients, pesticides and heavy metals by physically removing these constituents from the sloughs in areas where they occur at high concentrations, and redepositing them on land where they can be absorbed and retained; water circulation can also be enhanced by a recirculation pumping scheme.
- Vegetative buffers are well accepted as a means of intercepting and retaining various types of surface runoff pollutants. At a minimum, they would be highly effective for filtering oil and grease; depending on their width and design, they potentially may be very effective as traps for sediment, nutrients, pesticides and heavy metals also.

Urban Source Control BMPs

Public Education. A public education and participation plan provides a strategy to educate city workers, industry, and the general public about the importance of protecting the surrounding water resources of the area. The program can make people aware of the hazards of commonly used materials and what kind of impact they can have on the environment. Watsonville currently provides public education explaining how pollutants enter the slough system. Advertisements for clean-up days, toxic recycling and curb side pick-up programs are placed in the local newspaper. City personnel participate in outreach programs in the schools in regard to water conservation and water quality. Pamphlets explaining non-point source pollutants are also distributed as billing inserts, and could be written in English and Spanish. Other examples of education programs include signage or labels at storm drain inlets (see below), slough crossings, and parking areas that warn against the dangers of dumping a toxic materials into the storm drain system or sloughs.

TABLE 7-2

SUMMARY OF
SOURCE CONTROL BMPSs

SOURCE CONTROL BMPs	WATER QUALITY PROBLEM ADDRESSED							
	Sedimentation	Nutrients	Ammonia	Pesticides	Heavy Metals	Oil and Grease	Debris	Water Flow/Circulation
URBAN AREAS								
• PUBLIC EDUCATION	x	x	-	x	x	x	x	-
• OIL/TOXIC RECYCLING	-	-	-	x	x	x	x	-
• HOUSEHOLD HAZARDOUS WASTE COLLECTION	-	-	-	x	x	-	x	-
• STORM DRAIN SIGNAGE	-	x	-	x	x	x	x	-
• TRASH RECEPTACLES/SIGNAGE @ PUBLIC ACCESS AREAS	-	x	-	x	x	x	x	-
• SANITARY SEWER LEAKS/SPILL PREVENTION	-	x	x	-	x	x	-	-
• VEHICLE USE REDUCTION	-	-	-	-	x	x	-	-
• STORM DRAIN CLEANING	-	x	-	-	-	-	x	x
• YARD DEBRIS PICK-UPS	-	x	-	-	-	-	x	-
• IMPERVIOUS SURFACE LIMITS FOR NEW DEVELOPMENT	x	-	-	-	x	x	-	x
• INDUSTRIAL SITE RUNOFF CONTROLS	-	x	x	x	x	x	x	-
• STORM DRAIN DESIGN PRACTICES								
- INFILTRATION DRAINAGE	x	x	-	x	x	x	x	x
- DETENTION	x	x	-	x	x	x	x	x
- VEGETATED FILTERS (BIOFILTERS)	x	x	-	x	x	x	x	-
- OIL/GREASE SEPARATORS	-	-	-	-	-	x	-	-
• CONSTRUCTION SITE EROSION CONTROL	x	x	-	-	-	-	-	x
• STREET SWEEPING	x	x	-	-	x	-	x	-
AGRICULTURE								
• VEGETATED FILTER STRIPS	x	x	-	x	-	-	-	x
• PESTICIDE MANAGEMENT	-	-	-	x	-	-	-	-
• IRRIGATION CONTROL	x	x	x	x	-	-	x	x
• FERTILIZER MANAGEMENT	-	x	x	-	-	-	-	-
• EROSION CONTROL	x	x	-	x	-	-	x	-
RURAL RESIDENTIAL								
• SEPTIC	-	x	x	-	-	-	-	-
• LIVESTOCK CONFINEMENT PRACTICES	x	x	x	-	-	-	-	-

TABLE 7-3

RATING OF MANAGEMENT MEASURE EFFECTIVENESS

DOWNSTREAM TREATMENT MEASURE	WATER QUALITY PROBLEM ADDRESSED							
	Sedimentation	Nutrients	Ammonia	Pesticides	Heavy Metals	Oil & Grease	Debris	Water Flow/Circulation
• WET DETENTION/SEDIMENTATION BASINS	1	2	2	2	2	2	2	2
• DRAINAGE MODIFICATIONS	2	2	2	2	2	2	2	1
• CHANNEL DREDGING	1	3	3	3	3	3	2	2
• CHANNEL FILLING	2	2	2	2	2	2	2	3
• CONSTRUCTED WETLANDS	2	2	2	2	2	2	2	2
• FLOW DIVERSION	2	2	2	2	2	2	2	3
• SLOUGH/TAILWATER RECIRCULATION	2	1	2	1	1	2	3	1
• VEGETATED RIPARIAN BUFFERS/FILTER STRIPS	2	2	2	2	2	1	2	3
• FLOW AUGMENTATION	3	2	2	2	2	2	3	1
• WATER LEVEL CONTROLS	3	2	2	2	2	2	3	2

RATING CODE:

1 = High degree of effectiveness
2 = Moderate degree of effectiveness
3 = Little or no effectiveness

Oil and Toxic Material Recycling. Recycling programs are intended to make it easier and more convenient to dispose of used motor oil and other toxic compounds used in the home. Usually municipal collection centers are set up and funded by the city. This may include payment of incentives to the local automotive service industry to recycle oil and automotive products. The City of Watsonville currently sponsors a curbside pick-up program for used motor oil and filters and has co-operative oil recycling programs with several automotive stores.

Household Hazardous Waste Collection. Improper disposal of hazardous household chemicals can adversely affect surface and groundwater quality. Collection programs, similar to recycling programs, provide and encourages people to properly dispose of their household hazardous waste. This can be accomplished by mobile collection centers, curbside collection, or a combined program. The aim is to get people to dispose of their hazardous compounds in a simple, easy, appropriate way. The County landfill currently has a program in place that allows residents to make appointments to drop off and dispose of their household hazardous waste.

Storm Drain Signage. This practice is part of a public education campaign to teach people about where the storm drainage system leads. This is accomplished by marking the storm drain inlets with markings that say, for instance, "No dumping - drains to Bay/Watsonville Slough". This is designed to stop illegal and inappropriate dumping of materials such as waste motor oil or radiator fluid. The City of Watsonville has implemented a storm drain signage program. Currently, over 80 percent of the City storm drains have painted signage in both Spanish and English; however, many are in need of re-painting.

Trash Receptacles/Signage at Public Access Areas. This practice includes placement of signs and trash receptacles in areas that have traditionally been used as dumping spots for household waste, construction spoils, and yard debris. The aim is to discourage people from dumping material into the slough areas. This is currently a problem, especially in and around the urban interface in Watsonville, Struve, and West Branch Sloughs. Watsonville has placed some signs within the slough areas; however, many of the access areas are privately owned. The City is working with land owners to clean-up and prevent trash from accumulating in these areas.

Sanitary Sewer Leaks/Spill Prevention. This is a normal activity of the City or sanitary district which entails the implementation of control procedures for identifying, repairing, and remediating sewer blockages, infiltration and inflow (I & I) of groundwater and runoff into the sewer lines, and wet weather overflows from sanitary sewers into the storm drain system. This is implemented by identifying and correcting areas with high I&I or inadequate sewer line capacity, and conducting routine maintenance. As a consequence of the 1989 Loma Prieta earthquake, the City of Watsonville, with assistance from the Federal Emergency Management Agency (FEMA), is implementing a multi-million dollar sewer repair and upgrade program.

Vehicle Use Reduction. Automobiles are a major contributor of non-point source pollutants. Reducing their use can have a substantial effect on pollutant load. Reducing automobile use may include sponsoring ride share programs, providing bike lanes and easy access for alternative transportation, establishing trip reduction programs for major employers of the area, and encouraging land use patterns that enhance the use of alternative transportation modes (i.e., compact, mixed-use development). The City of Watsonville has adopted a trip reduction ordinance and is participating in a variety of regional efforts to reduce automobile trips, including founding sponsorship of the Pajaro Valley Transportation Management Agency (PVTMA).

Storm Drain Cleaning. This practice covers the routine or special cleaning of the storm drain system to remove debris, sediments and other materials before they are washed into the sloughs. The City would locate areas where accumulating debris and sediment is a problem and put them on a routine maintenance program. This would include any grease traps and catch basins which are currently not well maintained. Watsonville presently carries out limited storm drain cleaning in connection with its sewer rehabilitation program.

Yard Debris Pickups. This is a program to make it easier and economical for people to remove and dispose of yard debris and junk. Usually, cities sponsor spring and early fall clean-up days, where debris and junk is picked up from the curb at no charge. Watsonville currently sponsors and promotes clean-up days. These are usually advertised in the local newspapers.

Impervious Surface Limitations. This practice would involve restrictions on the amount of paved area and/or impervious surfaces for new development. By reducing impervious surfaces, such as roadways, driveways, parking lots, etc., the amount of pollutants that may accumulate on them and subsequently be washed off into the storm drain system is reduced. This is also intended to maintain infiltration - groundwater recharge rates as close to native conditions as possible. Providing vegetated breaks between impervious surface areas can also reduce peak runoff rates and associated erosion. An example would be to route the flow from roof gutter down spouts to vegetated or rock lined areas rather than to paved driveways.

Industrial Site Runoff Controls. This covers runoff controls for industrial activities such as storage yards, wash off areas, fueling areas and other industrial outdoor work areas. Control measures such as berming and confining area runoff, constructing roofed areas, diverting surface runoff into the sanitary sewer, and providing oil and grease separators are some of the common techniques used to control runoff from industrial areas. These controls are typically implemented in connection with Waste Discharge Requirements (WDR) and National Pollutant Discharge Elimination System (NPDES) permits issued by the Regional Water Board (in San Luis Obispo) for certain types of industrial activities. A listing of existing facilities in the Watsonville Slough System area with WDRs and NPDES permits is provided earlier in this report (**Section 6**). The City has considerable interaction with industries regarding runoff controls. The majority of industries have NPDES stormwater permits and submit copies of annual reports to the City Source Control Program. The City has provided equipment, site evaluations and seminars on this subject to the industrial community.

Storm Drainage Design Practices. This relates to various types of designs and drainage measures to reduce non-point source pollutants. Common techniques include infiltration drainage trenches/basins, soil filtration, settlement ponds, vegetated buffer strips, grassed swales and ditches, and oil and grease traps. All of these techniques are designed to remove or settle pollutants picked up by runoff before they enter the storm drain system. These practices may either be installed by the City and/or mandated as conditions of approval for new development projects.

Construction Site Erosion Control. When an area is denuded of vegetation, the soil is more susceptible to the erosional forces of the runoff. This BMP deals with erosion control during the construction phase of a development project. Techniques such as seeding exposed slopes, building on-site sediment retention devices, and restricting grading or other activities are commonly used. Typically, this BMP is implemented through an adopted ordinance that mandates that a erosion control plan be prepared and implemented as condition of a building or grading permit. Usually both local and regional organization require erosion control to be conducted as a condition for a grading permit. Compliance with local building ordinances as well as NPDES approval is required for projects involving the grading of more than five acres. These permits, and the accompanying required erosion control practices, are designed to prevent erosion from large grading projects (i.e., home and commercial development construction) to impacts receiving water bodies such as Watsonville, Struve and West Branch sloughs.

Street Sweeping. Street sweeping reduces the discharges of pollutants to storm water from street surfaces by removing dirt and accumulated debris on a regular basis. Mechanical, vacuum and combination sweepers are used to remove the build-up of pollutants on the streets and parking areas of the urban area. The City of Watsonville currently conducts regular cleaning of City streets. The entire City undergoes sweeping every two weeks, with the downtown area receiving sweeping four times a week.

Agricultural Source Control BMPs

Erosion Control Practices. Agricultural areas have similar needs for erosion control as construction sites. The main differences are that erosion control practices for agricultural areas are usually permanent or semi-permanent structures or practices. Examples of these practices include the following:

- **Proper Tilling Practices**. The way a field is tilled and the alignment of rows on hillsides is important for soil conservation and erosion control. Rows should be oriented perpendicular to the direction of the slope. Rows parallel to slope allow for concentrated flow and accelerated velocities which gully formation and accelerated erosion.

- **Road Stabilization**. Numerous studies and observations show that road grades produce and have accelerated rates of erosion. Proper drainage, proper grading, and roadside ditch stabilization can minimize road erosion, as can the use of grasses as a roadway cover crop. Native bunch grasses are particularly effective because of their durability when driven on.

- **Drainage Control**. Drainage control measures are designed slow down and spread runoff on the hillsides, since concentrated flow creates erosion. The installation of features such as water bars, energy dissipators, flow diversions, terraces and proper drainage structures all aid in reducing erosion. When concentrated runoff is unavoidable, techniques such as the armoring of channels and/or the installation of drop structures, check dams reduce water velocities and scour potential.

- **Sedimentation Ponds**. These are created ponds or basins which collect runoff from the agricultural areas. The basins are designed to induce suspended sediment to deposit in the basin prior to leaving the site.

- **Cover Crops**. Short-lived annual grasses, usually planted in the fall, after the irrigation season, can be used to protect the soil in fallow or otherwise bare fields from rainfall impact and stabilize it against runoff-included erosion.

- **Irrigation Water Management**. Proper scheduling of irrigation applications along with proper design of irrigation systems to achieve uniform and efficient application of water can aid substantially in reducing unnecessary runoff from irrigated fields. Reducing this runoff also minimizes the transport of agricultural chemicals and soil into drainage ways and the bordering sloughs.

- **Critical Area Stabilization**. This practice covers the special erosion control efforts needed for critical erosion sites or features on specific sites. This may include repair and control of gullies, stream bank erosion protection, slope terracing and vegetation/revegetation of disturbed areas.

The NRCS estimates that currently about 70 percent of the farmers employ some BMPs, about 15 percent employ all available and applicable BMPs, and about 15 percent do not employ any agricultural of which to speak BMPs. There has been no monitoring or evaluation of the implementation of these BMPs on their effect on the Slough's water quality to date.

Erosion Control Implementation/Ordinances. In the Watsonville Slough System watershed the previously-described types of practices are especially important in the agricultural areas located in the surrounding hillsides. Both the Soil Conservation Service and the U.C. Agricultural Extension are heavily involved in educating farmers, through personal contacts and literature, on proper erosion control BMPs. However, implementation of erosion control is ultimately the responsibility of the individual land owners. The Santa Cruz County erosion control ordinance does not address agricultural practices and there are no other enforcement tools. The only exception is that the County mandates the farmers to clean sediment from County roadside ditches alongside farm fields, or pay a fee to the County for cleaning them. The City of Watsonville's erosion control ordinance also does not address erosion from agricultural practices within the City. Erosion control ordinances in other local jurisdictions (e.g., Napa County) have been expanded to include selective agricultural practices (e.g., hillside vineyards) where special erosion problems exist. Monterey County also has erosion control requirements that apply when grasslands are converted to irrigated agricultural uses. These ordinances basically require the preparation and approval of an erosion control plan, along with enforceable compliance with the accepted plan. This type of ordinance provision has some potential applicability in the Watsonville Slough area; but it would also not be able to deal with erosion problems associated with existing agricultural practices.

Pesticide Management. Even though most currently used pesticides rapidly breakdown to harmless by-products during the time in which they are still potent, there is a potential for them to do environmental harm if, for instance, they are washed or released directly into a water body. Appropriate management of pesticide use on agricultural land is essential to reducing the transport of these substances from the agricultural area to receiving waters. Management practices such minimizing spraying, using easily biodegradable formulas, applying pesticides only during the dry climatic conditions, and avoiding environmentally sensitive areas provide the basis for the proper best management practice for pesticide use. This BMP goes hand-in-hand with erosion control because pesticide residues are often transported to water bodies attached to eroded soil particles. It should be noted that all commercial applicators of pesticides must be licensed, and that application of certain state restricted pesticides requires a special permit. The County Agricultural Commissioner's office regulates and records amounts of all agricultural pesticides used in the County to help ensure utilization of appropriate pesticide BMPs.

Irrigation Control. Frequently, suspended sediment and chemical residues are transported to water bodies by improper irrigation control. Irrigation management practices include the proper maintenance, distribution and application rates for irrigation water. Inefficient or leaky irrigation systems can cause erosion and runoff from agricultural fields to impact local drainages and eventually the Watsonville Slough System.

Fertilizer Management. Fertilizer management is similar to management practices for pesticide applications. The aim of fertilizer applications is to minimize the amount of nutrients entering the local sloughs. The proper management of fertilizers includes soil fertility testing, adjusting application rates as needed, and applying fertilizers at the proper time of year under the right the climatic conditions. Fertilizer residues (especially nitrate) are also transported readily into the sloughs along with eroded soil; this adds to the importance of erosion control in the overall reduction of nutrient inputs to the sloughs. Special attention also needs to be given to fertilizer storage, mixing and distribution areas, such as the one in the upper reaches of Harkins Slough, as these represent potential sites for spills and/or runoff of concentrated fertilizer compounds. This applies to pesticide management, as well. Covered areas and runoff containment provisions are common and effective practices for control of this agricultural pollutant source. Mushroom farming operations, which involve substantial manure handling, are also a potential source of excess nutrients and ammonia.

Livestock Confinement Practices. When improperly managed, wastes generated from confined animal facilities can adversely impact ground and surface waters through the introduction of nutrients, salts, suspended solids, bacteria and other pollutants. There are numerous types of management measures and practices that can be implemented, including: (1) separating clean and contaminated water through runoff controls; (2) proper liquid waste collection and storage, including lineal ponds, fabricated holding tanks and waste treatment ponds or lagoons; (3) proper solid waste collection and storage, including contained storage areas to prevent contact with surface water and runoff; (4) excluding livestock from riparian areas; and, (5) providing vegetated buffer strips between heavy use areas and runoff channels. A confined animal facility in the upper watershed of Hanson Slough and Harkins Slough represents a potential source of animal wastes, as does the grazing of livestock in streamside areas.

Vegetated Buffer Strips. The installation of new and/or maintenance of existing vegetated buffer strips can be used as an urban source control BMP. Such buffer strips should be sited between impervious surface areas (e.g. parking lots) and wetland areas so as to prevent the transport of heavy metals and hydrocarbons (oil & grease) into the wetland area. Buffer strip would also be appropriate downstream from areas of active erosion such as construction sites. Generally speaking, wider and more level buffer strips are more effective than narrow, steep-sloped ones. Vegetated buffers should be maintained and/or enhanced where they already exist. Also, see discussion below of using buffer strips as downstream treatment BMPs.

Rural Residential Source Control BMPs

Septic Systems. Septic system practices come under the regulations of the Santa Cruz County Department of Environmental Health which focus primarily on proper siting design and installation for new systems. Septic tank pumping, inspections and repairs of existing systems also occur under a County-wide maintenance program to facilitate the correction of malfunctioning systems and inappropriate discharges into the sloughs. Santa Cruz County's septic system management program is one of the more comprehensive and advanced programs in California. The County has established a computerized data based to help identify and track septic system problems. The Watsonville Slough area is not presently known to be an area with significant problems, but occasional failures can occur almost anywhere.

Livestock Confinement Practices. Many of the rural residential properties in the slough area have livestock (i.e., horse stables). Livestock confinement areas can be a significant source of nutrients, bacteria, and other pollutants. Management practices for livestock confinement areas including proper location of facilities (i.e., away from creeks and sloughs), controlling runoff (i.e. diverting runoff away from water bodies), and proper collection and storage of manure stock piles (i.e. covered storage areas).

Vegetated Buffer Strips. The installation of new and/or maintenance of existing vegetated buffer strips can also be used as a rural residential BMP. Such buffer strips should be sited between wetland areas and potential sources of erosion or pollution (e.g. horse stables or other livestock areas) so as to prevent the transport of manure and other pollutants into the wetland area. Again, wider and more level buffer strips are more effective than narrow or steep-sloped ones, and also existing buffer strips should be maintained or enhanced.

Downstream Treatment Measures

Wet Detention/Sedimentation Ponds. The installation of wet detention/sedimentation ponds (i.e., permanent ponds) can be a very effective multi-purpose water quality treatment measure. The proper construction and maintenance of the pond will result in high removal rates of sediment, organic matter nutrients, and trace metals. The aquatic biological processes within the pond can achieve removal rates of soluble nutrients (nitrate and phosphate) which otherwise contribute to nutrient enrichment of downstream waters. A wet pond can render multiple benefits by providing stormwater detention pollutant removal, and landscaping/habitat improvement. Possible locations for wet detention would be alongside urban areas and at the end of the Beach Road Ditch.

The degree of pollutant removal within a wet pond is determined by the size and design of the pool and the characteristics of the urban pollutants. Important removal pathways of suspended pollutants and soluble nutrients are sedimentation and biological uptake, respectively. Pool volume is the greatest factor influencing pollutant removal; the larger the pond, the greater the pollutant removal. Properly designed wet ponds can provide an attractive habitat for vegetation, fish, and wildlife.

Drainage Modifications. This measure would entail modifying existing drainage structures to improve water flow, circulation and increase inundation area in the sloughs. The need for such drainage modifications is throughout the sloughs. The existing system of channels and pumps for the most part is detrimental to functioning and wetland resources of the sloughs. These modifications drain historic wetland areas to allow agricultural production within the slough bottoms. Examination of 1912 U.S.G.S. maps show that much of the channelization has been present for over 80 years. Drainage modifications may include the widening of incised drainage channels, modification of pump station operation, construction of berms or embankments to protect flooding of existing agricultural lands, while protecting the remaining lands.

Another possible option suggested by Technical Advisory Committee members is that of simply removing the topsoil presently covering much of the historic wetlands and allowing the marsh to grow back, providing a much larger and more diffuse area for pollutant removal. The topsoil pushed onto the marshland could be returned to surrounding land, raising its elevation. Industrial development occurring on the site could provide for drainage of parking and building subsoils into the slough basin, as the slough basin would be at a lower contour. The slough's water table could be maintained at this lower elevation by the ditches maintained downstream of the site. The wide slough basin would provide an extensive area to accommodate flood runoff, improving flood control and reducing the flood hazard to industry and commerce situated on the site. This would be an extremely complex, costly and controversial undertaking.

Channel Dredging. In order to maintain flood control and channel conveyance the lower sections of Harkins Slough and the freshwater section of Watsonville Slough are dredged of sediment that accumulates from erosion in the watershed and adjacent agricultural lands. Water quality conditions are improved by the physical removal of sediment (and attached pollutants) from the sloughs; however, the dredging practices themselves (backhoe and clamshell operations) also suspend large quantities of sediments, nutrients, pesticides and metals in the water column, resulting in a temporary, but potentially significant, localized water quality problem.

An alternative to the current dredging operations is the use of small suction dredges, which can operate in channels as small as five to six-feet wide. This dredging method requires a nearby land area for disposal and "decanting" of the dredged slurry. It would also have more significant equipment mobilization requirements than the present backhoe operation. Suction dredging would greatly reduce the suspension of sediments and pollutants as well as the disturbance of streamside vegetation. The Regional Water Quality Control Board favors suction dredging over the present clamshell and backhoe dredging methods.

Channel Filling. This management measure would involve filling portions of existing drainage channels within the sloughs to create a more dispersed flow and shallow spreading of water; the aim would be to increase runoff contact with soil and vegetation to improve water quality and to expand wetland vegetation areas. Areas where this may be applicable are in the channelized portions of the sloughs, especially Watsonville, Hanson, and Harkins Slough. This type of wetland restoration measure has recently been implemented in a portion of Hanson Slough (*personal communication, John Oliver, May 4, 1995*).

Constructed Wetlands. Constructed wetlands can enhance stormwater and irrigation runoff water quality by removing oil and grease and causing the settlement of pollutant-laden sediments. They work much the same way as wet detention structures previously described. This management measure can be very effective in treating highway runoff and small concentrated pollutant flows from adjacent urban areas within the sloughs. These wetlands can also provide wildlife habitat and buffers. In these locations, urban pollutants such as heavy metals, oil, and grease could be removed prior to transport to the lower slough areas. Ideally, constructed wetlands are designed to put pollutants in contact with soils and vegetation where a variety of natural treatment process can occur. However, wetland must have a continued year-round source of water supply to sustain the vegetation. Thus, wetlands sized and designed to intercept and treat summer nuisance flow and small, "first flush" runoff are likely to be most effective and viable. It is also imperative that the intended vegetation types and wetland habitat objectives be matched with the soil and hydrologic conditions at the site, and that the constructed wetland be carefully monitored and maintained during its initial years of operation. Areas that would be good candidates for this treatment measure are sloughs areas currently degraded by encroachment or drainage outfalls, or in connection with future urban development bordering the sloughs.

Flow Diversion. This management measure would involve intercepting runoff and drainage (e.g., tile drains and industrial site runoff) from pollutant generating sources and diverting it elsewhere for discharge. The possible locations for discharge would be the Watsonville sewage treatment plant or the Pajaro River, the feasibility and practicality of which may be questionable.

Slough/Tailwater Recirculation. A potential management measure in the lower freshwater portion of Watsonville Slough (above Shell Road) would involve the recirculation of agricultural return and natural flow of water in the sloughs during the summer and dry fall months. The recirculated water would be introduced directly to upstream slough channels or, preferably, applied as irrigation water to a newly created riparian/ wetland area along either or both sides of lower Watsonville Slough, below San Andreas Road. Water could be pumped from Shell Road Pump Station and/or the Beach Road Ditch. Water quality improvement would be gained by controlled infiltration, filtering, and contact with the soils and wetland vegetation in the streamside riparian buffer. The areas receiving the recirculated water will have to be monitored to ensure that there are no harmful accumulations of pollutants. If there are, the project will be appropriately modified or suspended. If the quality of water is adequate, then its reuse for crop irrigation could also be investigated.

Vegetated Riparian Buffers/Filterstrips. Vegetated/riparian buffer strips are most commonly used for pollutant removal along highways and adjoining residential areas; but they also have definite applicability in the Watsonville Slough System watershed, especially where the historic sloughs have been converted to narrow earthen ditches bordered closely by agricultural fields. The vegetative cover reduces runoff velocity from the adjoining fields, allowing runoff to infiltrate into the underlying soils. The filtering action of the vegetation causes deposition in low velocity areas, and infiltration into the subsoil removes pollutants from the runoff. This type of pollutant control is also beneficial where agricultural fields immediately border wetland areas which can be adversely impacted by agricultural site runoff. Vegetated buffers can also be established by widening and benching the main slough channel. The benched area of the channel provides an ideal zone for establishment of emergent and riparian vegetation which can intercept lateral pollutant inflow from farm fields, as well as filter and trap sediments carried in the slough channel from upstream areas.

Vegetated buffer strips are also useful along the edges of wetland areas, for pretreatment of polluted water before it gets into the wetland; buffer strips for this purpose work best on flat rather than steep areas. Buffer areas are also of value between wetlands areas and other land uses, such as agriculture, urban, industrial, etc. with regard to impacts on wetland habitat. Wetland buffer strips are very important in maintaining the habitat values of wetland systems and, generally speaking, wider buffer strips serve this purpose better than narrow ones.

Flow Augmentation. This measure would provide for the introduction of additional dilution flows to the sloughs during the dry season. The flow within the slough could potentially be augmented with a portion of the water diverted for the PVWMA recharge project or with reclaimed wastewater from City of Watsonville treatment plant, if either of these projects is implemented. The flow augmentation would be planned, optimally, to enhance water flow and circulation as well as to provide better quality dilution water in the sloughs. Specific release points for these supplemental flows would have to consider the economics of water delivery; but, in general, the objective would be to target dead end/stagnant areas and wetland restoration/enhancement areas requiring or benefitting from increased water flow.

Water Level Controls. This management measure would entail adjusting water levels in the slough and/or detention structures to achieve greater pollutant removal. This could be accomplished at road crossings within the slough system or at constructed wet detention basins within the watershed. The drawdown water levels during certain times of the year can enhance pollutant removal through greater soil and vegetative contact and oxidation processes. Alternatively, extended inundation throughout more of the year and maintenance of higher water levels would be beneficial to wetlands and wildlife habitat. Reducing pumping rates at the Harkins Slough pump station to seasonally flood additional bordering areas along the slough is an example of one such water level control option.

7.3 MANAGEMENT MEASURE IMPACTS

The various management measures identified in this section are oriented toward the control or correction of water quality problems in the sloughs. However, the measures all involve some monetary cost as well as possible impacts on other land and water management activities or environmental resources. One of the chief aims of this planning effort was to identify water resource management measures that are potentially beneficial to various watershed activities and uses. Estimated costs associated with recommended management measures are presented in **Section 8**. Provided here is a review of the potential or estimated impacts on other watershed activities/resources for each of the identified downstream treatment measures. Source control measures are not reviewed here, since the impact of such BMPs is confined largely, if not exclusively, to the specific land use area where it is applied. Also, source control BMPs cannot be readily compared with downstream treatment measure options, which have more specific parameters (e.g., costs, size and performance criteria/objectives). Also, for the most part, the effectiveness of source control BMPs in removing pollutants is not something that is predictable; these measures are simply the "best" or "right" thing to do where the pollution sources are so diffuse. This is the origin of the BMP concept.

A summary of estimated impacts of the various downstream treatment measure alternatives is provided in **Table 7-4**, in a matrix format. These impact ratings are best estimates by the consultant based on the general BMP concept; they are not a substitute for detailed impact evaluation of a specific project, which would have to be completed before implementation. The areas of potential impact considered in this review include agriculture, urban development, flood control, mosquito abatement, wetlands/biotic resources, and the Pajaro River Estuary (downstream receiving water). As indicated, the impacts are listed as significant(S), potentially significant (PS), negligible (N) or beneficial (B). In some instances, the effect of the management measure is indicated as ranging from beneficial or negligible to potentially significant; the difference in impact would be a function of the precise plan and design of the management measure. Following is a brief summary of the anticipated impacts for each downstream treatment measure.

Wet Detention/Sedimentation Basins

The installation of detention/sedimentation basins would be generally beneficial, except to the extent that they remove land from agricultural production or planned/existing urban development. Wet detention basins also add an additional burden for the mosquito abatement district; but the impact can be minimized with proper design and maintenance. Detention basins can be designed as an amenity to the neighboring residents (e.g., to create a park-like setting); but poor maintenance can also result in potential nuisances and hazards.

Drainage Modifications

Drainage modifications considered for Watsonville Sloughs would focus upon altering the flow pattern and inundation scheme of water in the sloughs. Improvements would have negligible to beneficial effects for most impact categories. Significant impacts would occur to adjoining land owners affected by the loss of crop land. An example of this is at the Harkins Slough pump station where the option of reducing or eliminating the pumping during portions of the year has been suggested us a means of returning more land to its former wetland conditions. This would mean the elimination of some of the currently farmed low lands adjoining the existing slough and wetlands, and possibly high groundwater conditions in the remaining agricultural lands alongside. The specific impacts to the adjacent farm land should be evaluated in the context of the overall farming operation that would be affected.

Channel Dredging

Channel dredging benefits drainage/flood control interests, mosquito abatement concerns and agricultural operations. The significant negative impacts stem from the elimination of riparian vegetation and stream habitat. Potentially significant impacts occur within the sloughs and

TABLE 7-4

SUMMARY OF
MANAGEMENT MEASURE IMPACTS

DOWNSTREAM TREATMENT MEASURE	Agriculture	Urban	Flood Control	Mosquito Abatement	Wetlands Biotic	Pajaro River Estuary
• WET DETENTION/SEDIMENTATION BASINS	PS	B/PS	B	PS	B	B
• DRAINAGE MODIFICATIONS	PS	N	PS	B/PS	B	N
• CHANNEL DREDGING	B	N	B	B	S	PS
• CHANNEL FILLING	PS	N	PS	PS	B	B
• CONSTRUCTED WETLANDS	PS	B/PS	B	PS	B	B
• FLOW DIVERSION	B/PS	B/PS	B/PS	B/PS	B/PS	B/PS
• SLOUGH/TAILWATER RECIRCULATION	N/PS	N	N	B/PS	B	B
• VEGETATED RIPARIAN BUFFERS/FILTER STRIPS	PS	B/PS	N	N/PS	B	B
• FLOW AUGMENTATION	N	N/B	N	B	B	PS
• WATER LEVEL CONTROLS	PS	N	PS	B/PS	B/PS	PS

<u>IMPACT CODE</u>:

S = Significant
PS = Potentially Significant
N = Negligible or None
B = Beneficial

downstream as a result of the suspension and release of nutrients, pesticides, metals and sediment into the water column during the dredging operations. Conversion to the use of mobile suction dredges would reduce these significant impacts, but not necessarily eliminate them. Suction dredging would require more planning and arrangements with the bordering land owners, for the temporary settling basins needed for this type of dredging (as compared with the current backhoe operations).

Channel Filling

Filling of existing channels to force the water flow into a more dispersed, overland pattern has the potential to be beneficial through creation of increased wetland area and improved water quality delivered to the Watsonville Slough and Pajaro River estuaries. However, potentially significant drainage problems may be created for adjoining agricultural lands and overall flood control operations, as well as increased demands for mosquito abatement where shallow ponding occurs. Possible mitigation for increased flooding may be the construction of levees or berms which protect adjoining agricultural fields from prolonged inundation (per Drainage Modifications).

Constructed Wetlands

Constructed wetlands would be generally expected to have similar beneficial impacts and potentially significant impacts as previously described for wet detention/sedimentation basins. Maintenance and monitoring of constructed wetlands would be important to assure the vegetation and treatment objectives are achieved. Also, the wetland should be designed to minimize potential mosquito habitat. In cases where wetland creation/restoration involves the installation of levees or berms, higher groundwater levels may result. This has the potential to negatively impact adjoining agricultural fields from water seeping up into the root zones of these surrounding fields. The impact for potential higher groundwater levels caused by wetland creation/restoration activities should be assessed on a site-by-site basis.

Flow Diversion

There is no apparently viable flow diversion plan for the Watsonville Slough System. Such a management measure would provide for bypass of high pollutant loads during certain times of the year or from certain sub-basins. Because of the uncertainty as to how such a scheme might be structured for the Watsonville Slough System, all impact categories are indicated as ranging possibly from beneficial to potentially significant.

Slough/Tailwater Recirculation

Recirculation of water from the Beach Road Ditch, the Shell Road Pump Station and/or the Harkins Slough Pump Station back through the slough system would have generally negligible to beneficial impacts because of the pollutant removal and wetland/vegetation enhancement achieved. Potentially significant impacts would occur to agricultural interests to the extent that land is taken out of production, e.g., for application of the water to a newly created/enhanced riparian zone. The specific impacts to the farm land should be evaluated in the context of the overall farming operation that would be affected; generally, the larger the farm, the less the impact. The relative productivity of the streamside soils would also be a factor in this analysis. Additionally, this measure could increase the amount of area requiring mosquito surveillance and abatement. Recirculation of the water for strategic discharge to existing dead end/stagnant portions of the sloughs would have no apparent adverse impacts.

Vegetated Riparian Buffers/Filter Strips

This alternative would have similar impacts to wet detention/sedimentation basins and constructed wetlands. The main impacts would be associated with the conversion of land area to "non-productive" uses; and there is also the potential to create mosquito management problems, depending upon the location, access provisions and design. Beneficial impacts would stem from the biological and visual amenities as well as pollutant removal for enhancement of conditions in the sloughs and to downstream receiving waters.

Flow Augmentation

Possibilities for flow augmentation might potentially include the use of reclaimed wastewater from the Watsonville wastewater treatment plant and groundwater pumped back into the system from the PVWMA Aquifer Recharge Storage project, if either project is implemented. The addition of water during the low-flow summer season would have either negligible or beneficial impacts throughout the Watsonville Slough System, attributable to the improved circulation of water, dilution of pollutant concentrations, and water supply to vegetation in the sloughs. The only potentially significant impact would be associated with the increased freshwater outflow into the Watsonville Slough and Pajaro River estuaries during the summer sandbar closure period. This could be detrimental to aquatic species and vegetation presently adapted to the summer brackish conditions in the lagoon.

Water Level Controls

Altering water levels in the sloughs to enhance pollutant removal is potentially feasible at some slough junctions; this could be done in conjunction with drainage improvements and would generally have beneficial impacts. There is the potential that changes in water levels from current conditions (e.g., dropping the summer ponded water levels) would decrease the amount of perimeter wetland area or, at a minimum, convert permanently ponded areas to seasonal wetlands. A greater mix of ponded and seasonal wetlands could offer greater ecological diversity in the sloughs, which is generally more desirable from a biological standpoint. However, there may also be merit to the idea of decreasing pumping rates to induce greater innundation (see Drainage Modifications above). As previously noted, this approach would take bordering agricultural land out of production (with potential impacts to farmers, as noted) and return it to a condition approximating its former wetland character.

7.4 HABITAT ENHANCEMENT OPPORTUNITIES AND MANAGEMENT NEEDS

Although the Watsonville Slough System provides regionally significant, valuable, and unique habitat, it is only a small fraction of the original wetland resource. The Slough system has potential for habitat improvement which should be integrated with water resource and water quality management efforts. Also, it is important to protect the existing wetland resources while preventing new problems or worsening of existing problems in the future. This may include protection of existing wetlands and maintenance of buffer areas adjacent to agricultural and urban land uses. Control of urban and agricultural non-point source runoff, as addressed through BMPs is important to sustain the health of the wetland ecosystem. This section is included here because the goal of habitat enhancement is highly consistent with the goal of water quality improvement. While the overall goal of this project is to prepare a plan to improve water quality in the slough system, the plan should not focus solely on water quality to the exclusion of closely related concerns. One of the primary reasons for improving water quality is for the enhancement of fish and wildlife habitat. Therefore, it is appropriate to list here some alternatives that would improve the habitat values of the slough system. Additionally, while not all of the habitat enhancement alternatives listed below would directly improve water quality, many of them would enhance filtration of non-point pollution, in addition to improving habitat in other ways.

In reviewing the results of previously completed biological surveys and planning studies for areas of the Watsonville Slough System, as well as the results of investigations for this 205(j) project, a number of habitat restoration and enhancement opportunities are apparent. Additional and more detailed biological inventories and planning studies are needed to identify specific enhancement locations, secure the support and cooperation of the landowners, and prepare the required implementation drawings and specifications. The following outlines and describes general habitat enhancement possibilities for the area.

Increase Ratio of Open Water to Emergent Marsh

In most years of normal rainfall, the estimated current ratio of seasonally flood open-water areas to emergent marsh is much less than 1:1. The desired ratio for optimum waterfowl habitat is 2:1. Areas of open water can be increased by such means as filling-in man-created slough channels, and installing hydraulic structures in slough channels that allow water levels to be regulated; i.e., raised to create open water and drained, as needed, for flushing.

Increased of Permanent Open-Water Area

The amount of persistent shallow open-water areas (that are favored by dabbling ducks) and deeper permanent ponds (that provide habitat for diving ducks and resident waterfowl) appears to be limited in the slough system. Water control structures, slough channel filling and selective diking can be used to expand open-water habitat and extend its persistence. Possibly the least costly and most effective way would be to selectively excavate depressions onto the marsh plain at locations and elevations which would intercept groundwater. This is what was effectively accomplished in associated with the mid-1980s peat minimizing operation in lower Harkins Slough. These created ponds could have habitat islands and be irregular shaped with gently sloping edges to allow for establishment of emergent marsh vegetation. A maximum water depth of five feet would be sufficient to insure permanence of the water feature. Such potentially stagnant open water bodies would require monitoring and management to insure success.

Restore Brackish Marsh

Portions of the non-tidal brackish marsh in the vicinity of the Shell Road pump station are degraded and can be enhanced and restored. The elevation normally occupied by transition zone and peripheral halophyte species (jaumea, frankenia, salt grass, slat bush) and adjacent high quality upland refugia for flood escape are missing or are of poor quality and dominated by wild raddish and hemlock. These areas could be enhanced, by a program of weed control, seeding and planting native salt-tolerant plants.

Enhance and Expand Freshwater Marsh

Several permanent ponds have limited areas of nearby emergent marsh vegetation, somewhat reducing their overall value. Other areas of emergent marsh are weedy with monocultures of pond smartweed (*Polygonum coccinium*). Seasonal wetlands in many areas are also dominated by introduced annual grasses and water tolerant weeds such as cocklebur, dock, wild raddish, pond hemlock. Habitat value of these areas can be greatly increased by instituting an integrated vegetation management program that results in the control or reduction of the numbers of non-native plants and an increase in the number and diversity of natives. This can be accomplished over time through a program of selective herbicide applications, mowing prior to seed set or seed maturity, planting, and control of water levels that favor targeted desirable plants. Such programs are often labor intensive and require a number of years of monitoring and follow-up management to be successful.

Create and Expand Central Coast Arroyo Willow Forests

Although it appears that many areas with suitable conditions for willow woodlands can re-establish themselves naturally, expansion of this habitat type, where deemed desirable and appropriate, can be hastened by planting willow cuttings. Live cuttings of willows should be inserted in the ground at spacings of three to four feet. It may be desirable to obtain the cuttings from various parts of the watershed to include some genetic diversity in the stands for increased disease and insect resistance. The willow thickets may have to be entered periodically for thinning and limbing to create more desirable tree forms and reduce crowding.

Increase Structural Complexity and Diversity of Riparian Forests

Most of the riparian forests of the Watsonville Slough System were removed and severely impacted by agricultural activities dating back to the 1860s. Although pioneering willow species are fast becoming re-established in many areas, this early stage colonizing community does not provide the same diversity of wildlife habitat as a riparian forest, which typically contains a wider mixture of tree and shrub species of various age and size classes. Currently, it is not clear what the original extent of such a mixed deciduous riparian forest was in the slough system. It is likely that open water and emergent marsh vegetation dominated the slough bottoms, with shrubby willow thickets, extending to the edges of the slough bottoms and along areas of defined channels. However, judging from soils and hydrologic conditions, it also appears that there were many areas where such mixed deciduous forest may have also occurred.

Desirable sites for riparian forest establishment could be identified and steps taken to re-establish and manage this limited, but valuable resource through a land acquisition and planting program. The most favorable sites appear to be the toe slopes of north exposures of the Harkins, West Branch, and Hanson Sloughs. Typically, such a riparian forest would have the following characteristics and management goals:

- Basal area of over 150 square feet with more than 300 stems per acre;
- Canopy cover of over 80 percent;
- A ratio of 60 percent deciduous trees to 40 percent evergreen trees and shrubs; no single species more than 30 percent of cover;
- Multiple layered canopy with occasional openings in canopy;
- Areal extent of at least two-acre blocks or patches; and,
- At least one dead snag per acre, with downed logs and brush piles allowed to remain artificially placed.

Protect, Expand and Manage Coastal Oak Woodland

Oak woodlands are not extensive within the slough system compared to their probable historical distribution. Oak woodlands provide valuable habitat and could be protected, expanded and managed with an acquisition and management program. Favorable areas for establishment and management of oak woodland are the north slopes of Harkins, West Branch and Hansons Sloughs.

Many of the principles of managing a mixed riparian forest will apply to an oak woodland where the goal is to achieve richness in numbers and kinds of species. Typically, such an Oak woodland would have the following management goals:

- Basal area of 40 to 80, with at least 100 stems per acre;
- Canopy cover of 40 to 80 square feet, with more than 100 stems per acre;
- Mixture in age class of saplings, young, mature and decadent trees with at least one snag per acre;
- Blocks of at least three acres; and,
- Tree cover dominated by Coast live oak (at least 70 percent).

Provide and Protect Movement Corridors between Significant Wetland Communities

Although generally not an obstacle for birds, many other amphibians, reptiles and small mammals require secure, continuous movement corridors in order to travel between differing types of habitat needed for meeting their daily foraging needs or completing their life-cycle. Much of the existing riparian and woodland habitat is fragmented in patches that may be too small to meet the needs of larger animals. Existing movement corridors need to be preserved and protected. Possible movement corridors between fragmented habitats could be identified and enhanced. Many times movement corridors are riparian strips which follow streams. Such riparian corridors with appropriate buffers can be established along many of the slough channels and tributary valleys to link various fragmented habitats, as well as upland areas throughout the watershed.

Enhance and Protect Upland Areas

Habitat enhancement and management of the slough complex must consider not only the wetland areas, but also native and disturbed upland areas. Wetland and upland communities are biologically important because their ecosystem functions are closely inter-related. U.S.D.A. programs such as the Partners in Wildlife and Conservation Reserve can be utilized more fully to preclude the most sensitive and erosive native soils from being converted to agriculture, to enhance and manage these areas, and possibly return marginal farmland to wildlife and watershed uses. Urban development in upland area can also pose problems from encroachment and hydrologic changes; and these need to be anticipated and mitigated. See discussion in **Section 4.7** regarding urban impacts and current efforts by the City of Watsonville to address these issues.

Upland management programs could include gully rehabilitation, fencing and enhancement of riparian corridors and adjacent buffer strips, planting or leaving portions of the crops in the fields for wildlife use, control of exotic plants, such as broom or pampass grass, or less desirable plants such as coyote bush. Re-establishment of native perennial grasslands might also be a management goal for some areas. Upland meadow and grassland areas are particularly important as foraging habitat for birds of prey.

Control of Invasive Undesirable Plants and Aggressive Exotic Species

Although it is currently only a localized problem within portions of the slough system, control of undesirable species may require more management attention in the future.

Perhaps the most difficult problem to deal with is the establishment of the introduced bullfrog throughout much of the watershed. The bullfrog frequently displaces the native red-legged frog. In addition, bullfrogs may feed on eggs and larval stages of both the Santa Cruz long-toed and Tiger Salamanders, threatening their populations. The mosquito fish, introduced into the slough system as a more natural way to control mosquitos in the 1970s, may also predate salamander eggs *(Ruth, 1995)*. Mechanisms to control and eradicate bullfrogs without impacting other aquatic organisms are not well known at this time. In addition, alternatives to the mosquito fish for control of mosquito populations, such as the current practice of applying a light weight oil, may also be damaging to aquatic organisms.

Escaped ornamental landscape plants, such as poison hemlock, pampass grass, lombardi poplar, weeping willow, Italian alder, Black locust, and Acacia, also threaten the health and diversity of the slough system. Although many of these are related to native species, they may be more aggressive and overtake native habitats, displacing more desirable species. The introduced plants may be more susceptible to frosts, or inset and disease attacks, or may not provide the same habitat value as their local counterparts. Eradication and control of aggressive exotic plants is often difficult, as they may be vigorous seeders, or may sucker readily from cut stumps, underground rhizomes or root pieces. Many communities are attempting to manage this problem by establishing restrictions on use of undesirable landscape plants in areas adjacent to high value wetlands.

Protect and Manage for Designated Sensitive Species

Although the enhancement and management actions listed previously will greatly benefit most wildlife species, including a number of sensitive species, there are several especially important species of concern that may warrant individual or more selective enhancement measures. Such species include, for instance, the Santa Cruz long-toed Salamander and the Santa Cruz tarweed, both of which are federal and state-listed endangered species. Although their known habitats are protected from most adverse actions, the full distribution and extent of many of the species of special concern are not presently known. In addition, periods of prolonged drought or significant flooding may further stress declining populations. A program to identify populations of endangered species and evaluate potential habitat areas that meet their specialized requirements for enhancement and/or possible species re-establishment could be considered. This would also require considerable coordination and planning among the various resource agencies.

Alternative Mosquito Abatement Practices

Alternative measures for the control and abatement of mosquitos in the sloughs may be appropriate to consider as part of a long-term resource management plan. The aim would be to reduce the use of chemical sprays, the environmental consequences of which are not entirely known. Examples of alternative practices to be considered include:

- **Water Level Management**. The flooding and draining of marsh areas is often done to manage mosquitos; but, this would require considerable hydraulic control over the slough system which presently does not exist. Enhancement of water circulation would be easier to accomplish than flooding and draining entire marshes, and could greatly reduce mosquito production.

- **Mosquitofish**. Introduction of mosquito fish into the sloughs, along with provision of adequate continuous water depths for their survival is an alterative; however, Mosquitofish also predate on other aquatic organisms which makes this approach unattractive to the Department of Fish and Game and others.

- **Other Mosquito Predators**. Creation of habitat and encouragement of bats and swallows may diminish mosquito numbers to some extent, but its approach is not site specific. It is more effective to control mosquitos before they become adults. Also, bats in urban areas may be considered pests and can potentially carry rabies. Modification of the aquatic habitat to encourage insect predators of mosquitos may be beneficial. This could be achieved in some areas, for instance, by improving water quality or modifying vegetation. However, predators are opportunistic and will feed on a wide variety of organisms. Therefore, their impact on mosquitos is unpredictable, and depends in part on availability of alternative prey and the synchronicity of life cycles.

SECTION 8

RECOMMENDED MANAGEMENT PRACTICES AND STUDIES

The alternative management measures for water quality improvements presented in **Section 7** were reviewed and compared in regard to several factors, including: (a) effectiveness in addressing identified water quality/degraded wetland problems; (b) engineering technical feasibility; (c) impacts to other competing water/land management interests in the watershed; and, (d) likely ability to be implemented. From this review, an array of conceptual management measure recommendations were developed. These recommendations are described in this section, along with estimated costs, illustrative diagrams, and identified steps required for implementation. Also identified are additional studies where they appear to be warranted.

This list of alternatives and resulting recommendations was not based upon a conventional cost-effectiveness analysis, since a specific treatment objective was not defined as a common basis for comparison of alternatives. Rather, the analysis, in accordance with the defined scope and approach for the project, relied heavily on professional judgement of the consultant team to estimate the best means of improving water quality while at the same time balancing the competing interests of many different stakeholders. The analysis was, in essence, the classic multiple-objective planning problem for which there is no formula from which to determine the "right" solution. The analysis was complicated further by the assignment to focus on wetland enhancement and restoration options, without a cohesive wetland restoration or management plan. Complete definition of the sources of non-point source water pollution in the slough system was also not achieved from the review of historic data and the new sampling data developed by the project. Accordingly, the recommended downstream treatment measures listed in **Section 8.2** must be viewed as tentative, subject to completion of several additional studies (identified at the end of this section) that were not covered within the scope of this project.

8.1 RECOMMENDED SOURCE CONTROL BMPs

Nearly all of the source control BMPs described in **Section 7** have applicability and would benefit the water quality improvement efforts in the Watsonville Sloughs. Clearly, some measures would be more effective than others; some are more easily implemented than others; and, many of the identified BMPs are already in place. A cost effectiveness analysis of source control measures was not the objective or within the scope of this project; therefore, source control recommendations are limited to prioritized listing of BMPs according to their ability to address specific observed water quality problems in the sloughs, as well as their likely local acceptance and implementation. **Tables 8-1, 8-2** and **8-3** categorize the source control BMP recommendations as follows.

Type 1. These are BMPs which will have immediate benefits and can be implemented with relative ease (if not already in place).

Type 2. These are BMPs which have the potential to be effective, but which may be difficult to implement because of costs, land/water management conflicts, lack of regulatory programs, or other factors.

Type 3. These are BMPs which are desirable but will likely have relatively small impact on improvement of water quality in the sloughs as compared with Type 1 and 2 BMPs.

Tables 8-1, 8-2 and **8-3** also indicate the identified lead agency (or agencies) that would be responsible for implementation of the respective BMPs. Many of these BMPs have been, or are, in the process of being implemented. The City of Watsonville as previously discussed in **Section 7** is implementing many of the listed urban area source control BMPs.

Table 8-1
Type 1 Source Control BMPs

BMP Type	Responsibility/Lead Agency
Urban	
Public Education	City of Watsonville
Storm Drain Signage	City of Watsonville
Trash Receptacles/Signage @ Public Access	City of Watsonville/Santa Cruz County
Impervious Surface Limits for New Development	City of Watsonville
Industrial Site Controls	City of Watsonville/Santa Cruz County/Regional Water Board
Construction Site Erosion	City of Watsonville/Santa Cruz County/Regional Water Board
Storm Drainage Design Practices - Infiltration Drainage - Detention - Vegetated Filters/Buffer Strips	City of Watsonville/Santa Cruz County
Sanitary Sewer Leaks/Spill Prevention	City of Watsonville
Storm Drainage Cleaning	City of Watsonville
Oil/Grease Separators	City of Watsonville
Agricultural	
Irrigation Control	Landowner
Pesticide Management	Landowner

Table 8-1
Type Source Control BMPs (cont'd)

BMP Type	Responsibility/Lead Agency
Erosion Control Practices	Landowner
Confined Animal Facility Practices	Landowner, Regional Water Board
Vegetated Buffer Strips	Landowner
Rural Residential	
Vegetated Buffer Strips	Santa Cruz County, Landowner

Table 8-2
Type 2 Source Control BMPs

BMP Type	Responsibility/Lead Agency
Urban	
Vehicle Use Reduction	City of Watsonville/Santa Cruz County
Agriculture	
Fertilizer Management	Landowner
Erosion Control Ordinances	City of Watsonville, Santa Cruz County
Rural Residential	
Livestock Containment Practices	Santa Cruz County/Regional Water Board

Table 8-3
Type 3 Source Control BMPs

BMP Type	Responsibility/Lead Agency
Urban	
Oil/Toxic Recycling	City of Watsonville
Household Hazardous Waste Collection	City of Watsonville/Santa Cruz County
Yard Debris Pick-up	City of Watsonville
Livestock Confinement	Landowner
Rural Residential	
Septic Management	Santa Cruz County

There are significant opportunities to improve and expand the use of source control BMPs in the Watsonville Slough System watershed in both agricultural and urban areas. All reasonable efforts should be made to implement these measures and to focus monitoring, surveillance and enforcement attention on land owners and operators where BMPs are ignored or improperly applied. Existing pollution enforcement powers of the Regional Board and the Department of Fish and Game should be utilized, as necessary, to supplement voluntary compliance and educational efforts of the City, County and other resource agencies. History has shown that individual properties can have significant adverse impacts (e.g., fish kills) on the slough system through improper or illegal practices and discharges; correction and future prevention of these site specific problems may eliminate the need for more costly and difficult downstream treatment measures.

8.2 RECOMMENDED DOWNSTREAM TREATMENT MEASURES

Downstream treatment measures in the sloughs have the potential to effect the greatest degree of improvement in water quality and wetland conditions. From the range of alternatives described in **Section 7**, the measures recommended for implementation are as follows and indicated generally in **Figure 8-1**:

1. Constructed wetlands/wet detention or treatment of low-flow urban and highway runoff; located on the reach of Watsonville Slough both upstream and downstream of Lee Road and at the end of the Beach Road Ditch. As can be seen on the map, **Figure 8-2**, there are opportunities to connect the lands owned by the Department of Fish and Game on West Struve Slough with those owned or to be owned by the Department of Fish and Game in Harkins Slough with a constructed wetland. These opportunities should be recognized as having multiple benefits.

2. Slough and irrigation tailwater recirculation for high rate irrigation of a created vegetated/riparian buffer along the Watsonville Slough downstream of San Andreas Road.

3. Vegetated channel terrace and riparian buffers along reaches of Watsonville and Harkins Slough above San Andreas Road.

These recommendations incorporate most of the ten alternative downstream treatment measures identified and discussed in **Section 7**. The conclusions and recommendations reached in regard to the other specific alternative measures are as follows:

- **Channel dredging**, as currently practiced, is necessary to maintain channel capacity but is also detrimental to the water quality and habitat establishment. It will become more difficult to conduct the existing type of dredging operations if the recommended vegetated buffer strips are implemented. Conversion to alternative dredging methods (e.g., small suction dredge) and reduced dredging area should be considered.

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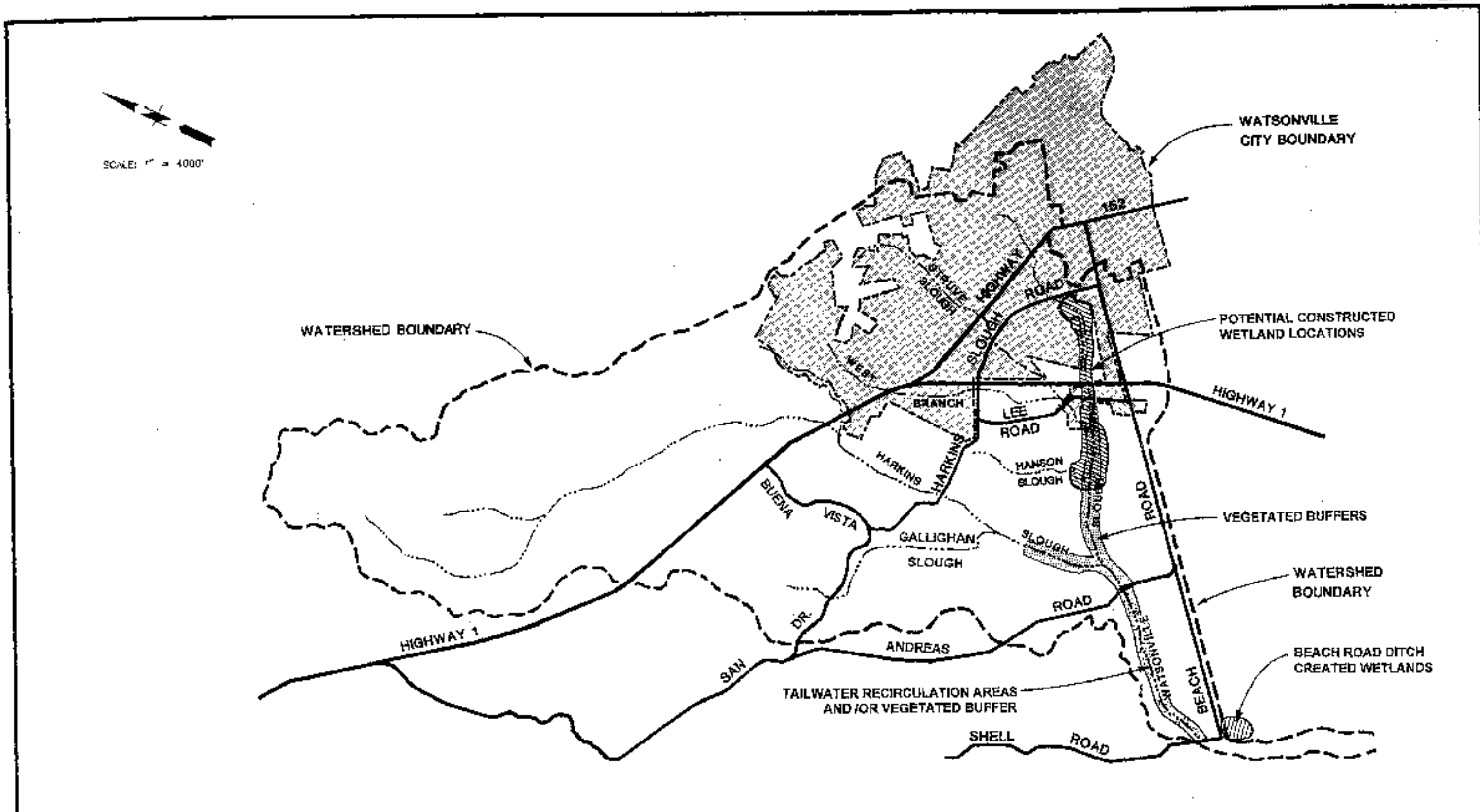

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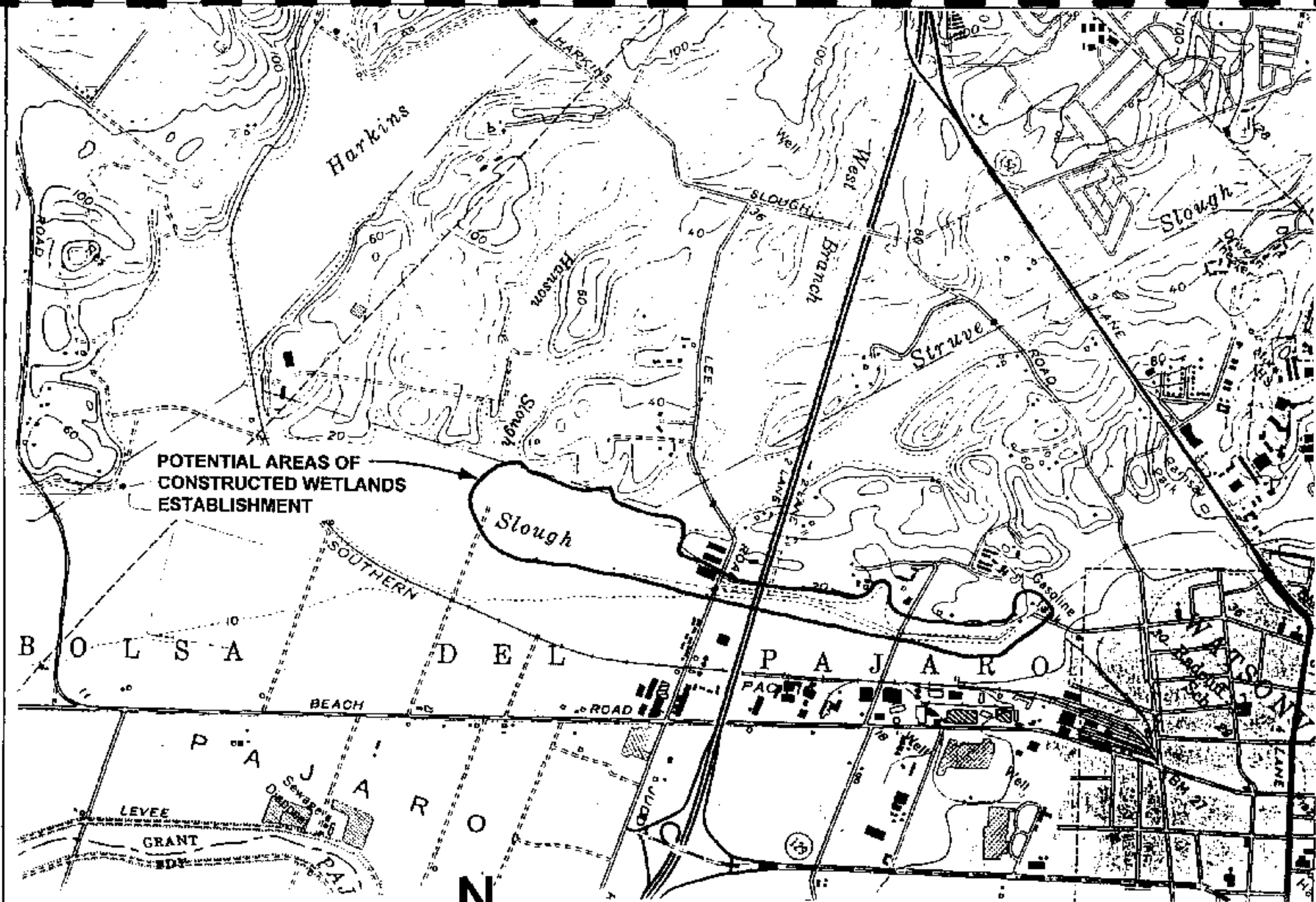
WATSONVILLE SLOUGH SYSTEM
LOCATION OF TREATMENT MEASURES

FIGURE **8 - 1**



APPROX. SCALE: 1" = 610'

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WATSONVILLE SLOUGH SYSTEM
POTENTIAL LOCATION OF CONSTRUCTED WETLANDS

FIGURE **8 - 2**

- **Flow augmentation** is recommended for further consideration; but it would be dependent on a separate project of either the PVWMA (Aquifer Recharge - Storage project) or the City of Watsonville (Wastewater Reclamation). Additionally, a flow augmentation project would need to account for, and mitigate, the possible downstream summer freshwater flow impacts to the Pajaro River Estuary due to increased outflows from the Watsonville Slough System.

- **Channel filling** and **flow diversion** alternatives do not appear to be viable or desirable management measures for the Watsonville Slough System in its entirety; however both of these measures would be incorporated to some degree as elements of the low-flow constructed wetlands and vegetated terraced channel concepts which are recommended.

The following paragraphs provide further description, illustration and estimated costs for the recommended downstream treatment measures. These measures remain conceptual at this point; no effort has been made to identify specific lands that would be required for their implementation. Clearly, significant land acquisition or donation would be required for these measures which would have to be coordinated and done with the consent of the affected landowners.

8.2.1 Constructed Wetlands for Urban Runoff and Agricultural Drainage

Description

Consistent with findings from most urban runoff studies, the water quality monitoring data for this project showed evidence of high concentrations of heavy metals (copper, lead, zinc and nickel) and oil and grease originating in the sloughs draining the Watsonville urban area and Highway #1. The concentrations (especially the metals) appear to peak during the low-flow period, and decline significantly during runoff events as a result of high dilution flows. Constructed wetlands developed to intercept and treat the low runoff flows and continuing "nuisance" flows throughout the year are recommended to reduce the water quality impacts from this source. A small constructed wetlands or wet detention pond at the end of the Beach Road Ditch is also recommended as an alternatives means of treating the nutrient and pesticides loads contained in this flow.

The constructed wetlands would include a mix of permanent water areas and bordering vegetated zones, subject to inundation by a portion of the runoff during and following storm events. The filtering action of vegetation and extended contact with soils allows wetlands to be effective in removing a variety of pollutants, including oil and grease, some heavy metals, nutrients and organic matter. High runoff flows would not enter the wetlands, but rather be bypassed or diverted directly downstream; this would avoid the scouring of pollutants that become trapped in the wetland soils and vegetation. A schematic illustration of this urban runoff treatment concept is shown in **Figure 8-2.** A schematic for a small wet pond for the Beach Road Ditch is illustrated in **Figure 8-6**; here the purpose would be to intercept the high nutrient loads and periodic pesticide residues contained in the flow from the sub-drains and from field runoff.

The potential pollutant removal benefits of these constructed wetlands are very roughly estimated as follows (WPCF, 1990):

- For Urban Runoff (based on 25 ac-ft annual flow)

  - Suspended Sediment (90% removal): 0.25 tons/year
  - Nitrogen (75% removal): 150 lbs/year
  - Heavy Metals (75% removal): 0.5 to 5 lbs/year
  - Oil and Grease (90% removal): 300 lbs/year

- For Beach Road Ditch (based on 100 ac-ft annual flow)

  - Suspended Sediment (90% removal): 12 tons/year
  - Nitrogen (75% removal): 4,600 lbs/year
  - Heavy Metals (75% removal): 2 to 10 lbs/year
  - Pesticides: 25% to 75% + removal

As proposed, the constructed wetlands would be essentially an "off-channel" flow-through detention area, incorporating some of the features of other management measures, such as wet detention, channel filling and flow diversion. The aim of this treatment concept is to target the low flows which are likely to have the highest pollutant concentrations as well as the initial pollutant wash-off (i.e., "first flush") during the rising limb of the storm hydrograph. In this manner land area devoted for the constructed wetland can be minimized and thus, the water needs to maintain wetland conditions (seasonal and permanent) can be met. In contrast, a wetland sized to accept all runoff would necessarily require a large land area commitment as well as a large ponded area to sustain water availability through the dry season. This type of constructed wetland would not be as effective for pollutant reduction or wetland enhancement.

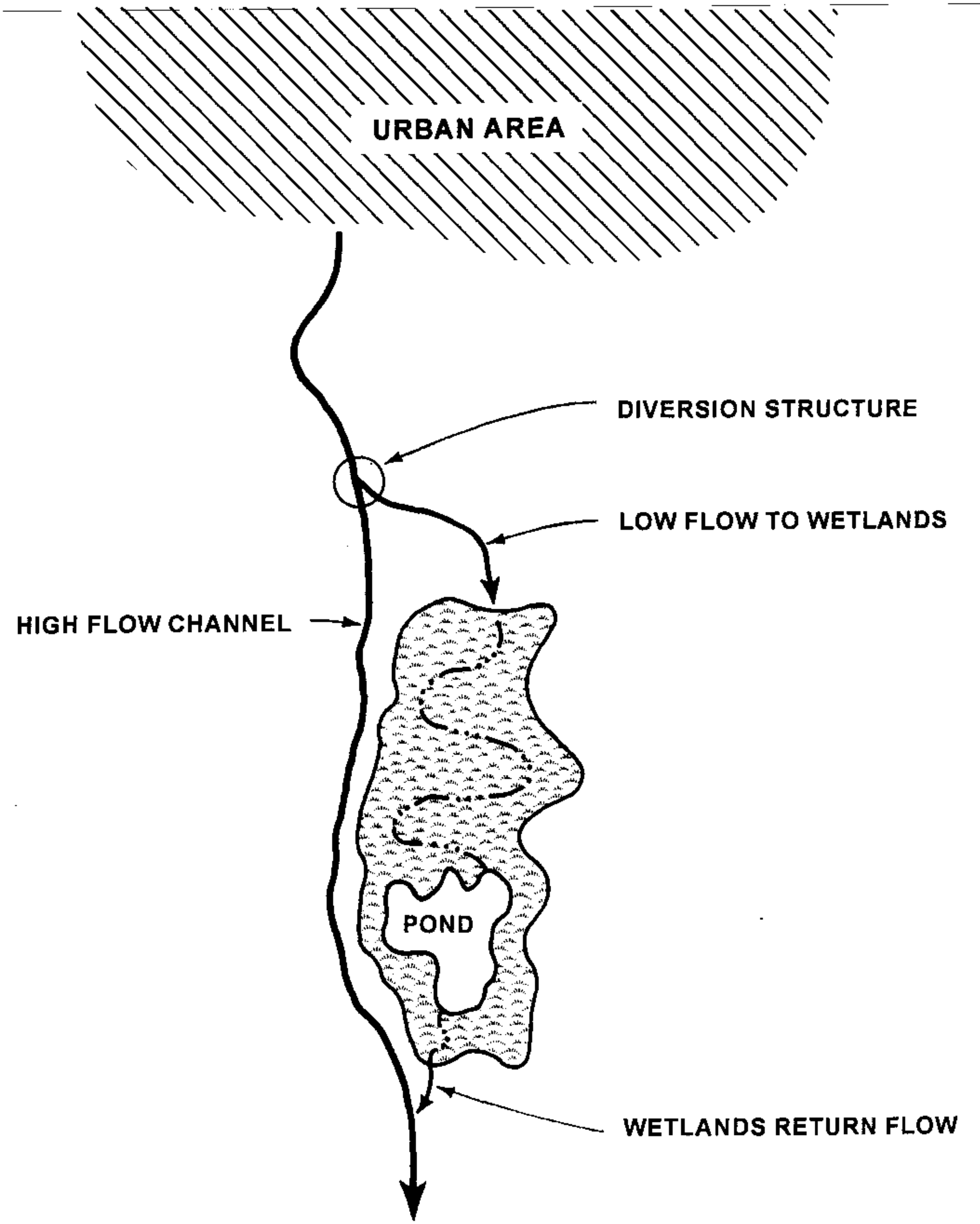
Key Design Features

The key design features and requirements for a constructed wetlands, as recommended here include the following:

- **High/Low Flow Diversion Structures**. This is an in-channel structure which would route all stream-flow up to a target level into the "off-channel" constructed wetlands. Flows in excess of the "target" level would "spill" (e.g., over a weir structure) into a high flow channel or culvert for conveyance around the wetlands. The size of the culvert, weir and other elements of this structure depend on the amount of drainage area and design flow to be handled.

- **Wetlands Area**. No firm design criteria have been established for the sizing of constructed wetlands for storm water treatment. The only general guideline suggests that wetlands larger than about one to two percent of the drainage area provide little additional water quality benefit. A one-percent wetland would be the target size for a low-flow treatment strategy.

- **Wetlands Configuration**. As illustrated in **Figure 8-3**, desirable features to incorporate in the wetland, for water quality and biological design purposes, include: (1) a meandering channel; (2) a permanent pool area; and, (3) graded areas that would be subject to seasonal



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WATSONVILLE SLOUGH SYSTEM
CONSTRUCTED WETLANDS FOR LOW FLOW TREATMENT

FIGURE **8 - 3**

or storm-related inundation. Gravel filter zones along the main flow-channel can also be used to enhance water contact with substrate.

- **Wetland Vegetation**. Wetland vegetation would be planted and established within the constructed wetlands. Native perennial wetland species such as rush and cattails would be established in and around the pool areas. The occasionally wetted upper area would be planted with native seasonal wetland species.

- **Return Overflow**. The maintenance of appropriate water depths in the permanent pool and other parts of the wetland would be controlled by one or more overflow structures; this is typically an adjustable weir or gate structure.

- **Operation and Maintenance**. The constructed wetlands would be a passive, flow-through treatment system. Seasonal adjustment of weirs or gates would be the only operational needs. Periodic inspection and cleaning of the inlet and outlet structures would be the primary maintenance requirement, along with routine collection of debris or nuisance floating material, which may vary according to public accessibility to the wetlands. Mosquito control may be necessary in permanent pool areas.

8.2.2 Slough and Irrigation Tailwater Recirculation

Description

High concentrations of pollutants accumulate in the lower portions of Watsonville Slough and Beach Road Ditch as a result of general watershed contribution, but also due to the predominance of agricultural activities and associated runoff and tile drainage in this lower area of the sloughs. This water is high in nutrients, metals, and pesticides. The construction of a slough and tailwater recirculation system in this area would provide an opportunity for pollutant removal by increasing the exposure of the water to wetland vegetation and soil prior to discharge into the tidal area. This is the only effective means of cleaning the lower portions of the sloughs of the pesticides (and possibly heavy metals) which have apparently accumulated over many years and continue to effect biotic species (through uptake and accumulation in tissue).

The proposed plan would provide runoff from the Beach Road Ditch and the Shell Road pump station and pump it to a newly enhanced riparian vegetated buffer, on either or both sides of Watsonville Slough, in the reach between Shell Road and San Andreas Road. For Beach Road Ditch this would be an alternative to the constructed wetland/detention pond described in the previous management measure recommendations. The recirculated water would be sprayed or released as overland flow at various locations along the vegetated riparian corridor. The concept is shown in **Figure 8-4** and **8-5**. This recirculation would be conducted in late spring , summer, and early fall; i.e., the dry, slow-flow season.

The potential pollutant removal benefits of a tailwater recirculation system are very roughly estimated as follows. These estimates are based on an assumed 20-acre riparian irrigation area and approximately 100 acre-feet annual recirculation flow:

- Suspended Sediment (100 % removal): 13.5 tons/year
- Nitrogen (90% removal): 5,600 lbs/year
- Heavy Metals (90% removal): 2.5 to 25 lbs/year
- Pesticides: 90%+ removal

As proposed, the recirculation and constructed wetlands would widen the lower slough channel above the Shell Road pump station and provide a more extensive vegetation buffer between agricultural areas and the slough channel, as well as recycling of pollutants to the soil. The aim would be to target low flows and agricultural drainage during the time when the pollutant concentrations in the sloughs are generally highest.

Key Design Features

The key design features and requirements for tailwater recirculation, as recommended here, include the following:

- **Pump Station Modifications**. A new pump station would be installed adjacent to the Shell Road pump station. This pump would collect water from the Beach Road Ditch and lower Watsonville Slough, pumping it along both sides of the slough.

- **Pipeline from Beach Road**. A new pipeline connecting the Beach Road Ditch with the new pump station would be installed to collect agriculture runoff.

- **Grading and Replanting**. A 50 to 100-foot buffer strip on both sides of the Watsonville A slough channel would be constructed. This would serve as a vegetation buffer from the agricultural field to south. The buffer strip would be a graded bench that slopes to existing channels.

- **Discharge Points**. Recirculated tailwater would be sprayed or discharged for maximum dispersal along the vegetated buffer strip.

- **Operation and Maintenance**. The recirculation would not be a passive system. Regular operation and maintenance procedures would have to be conducted to ensure the continual operation of system. Maintenance operation on the pump station and irrigation system would have to be performed. It is likely that some mosquito abatement procedures would have to be undertaken in the area.

8.2.3 Vegetated Buffers

Description

Extensive areas of Watsonville Slough and lower Harkins Slough have been channelized to facilitate drainage and agricultural production in the slough bottoms. There is a significant opportunity to enhance water quality and habitat along these reaches of the sloughs through the establishment of

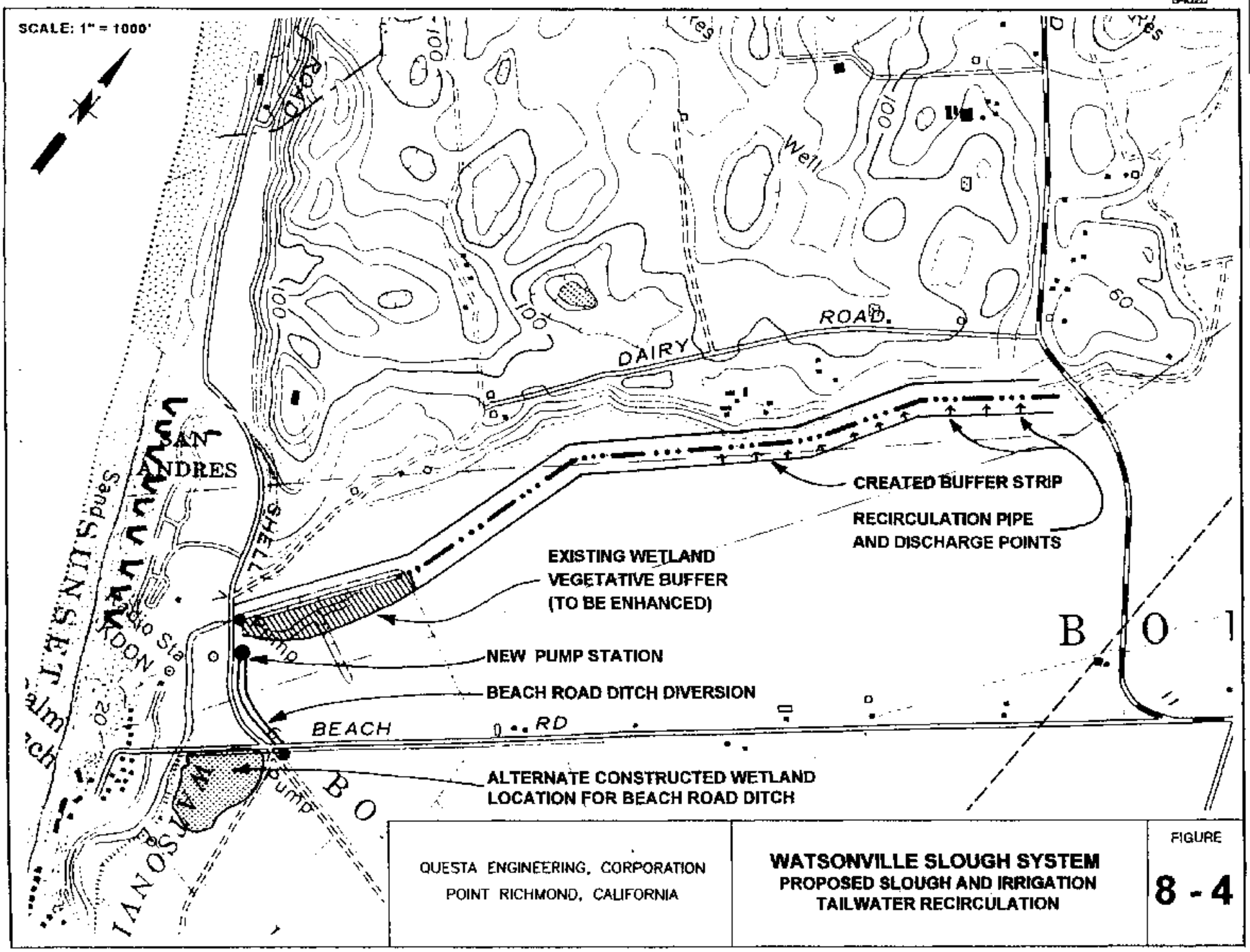

FIGURE 8 - 4

WATSONVILLE SLOUGH SYSTEM
PROPOSED SLOUGH AND IRRIGATION TAILWATER RECIRCULATION

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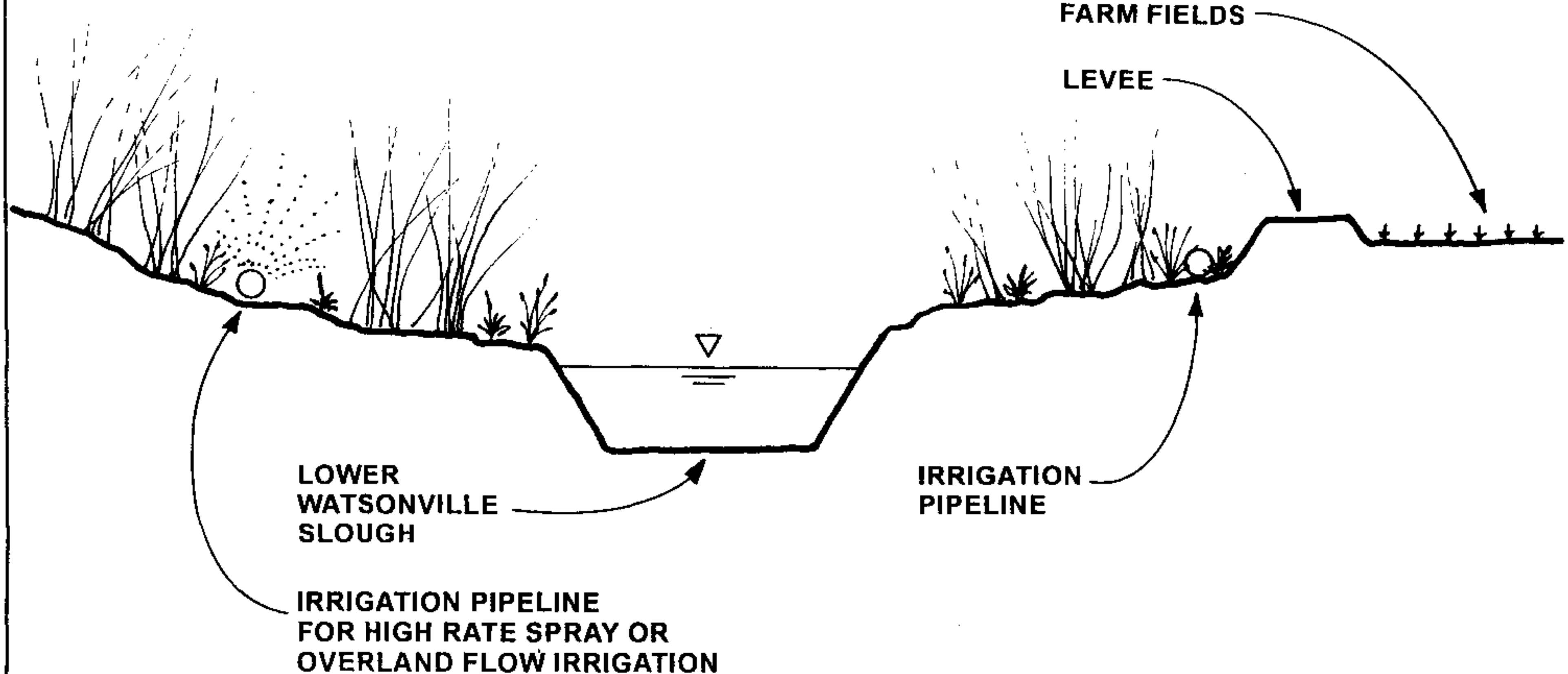

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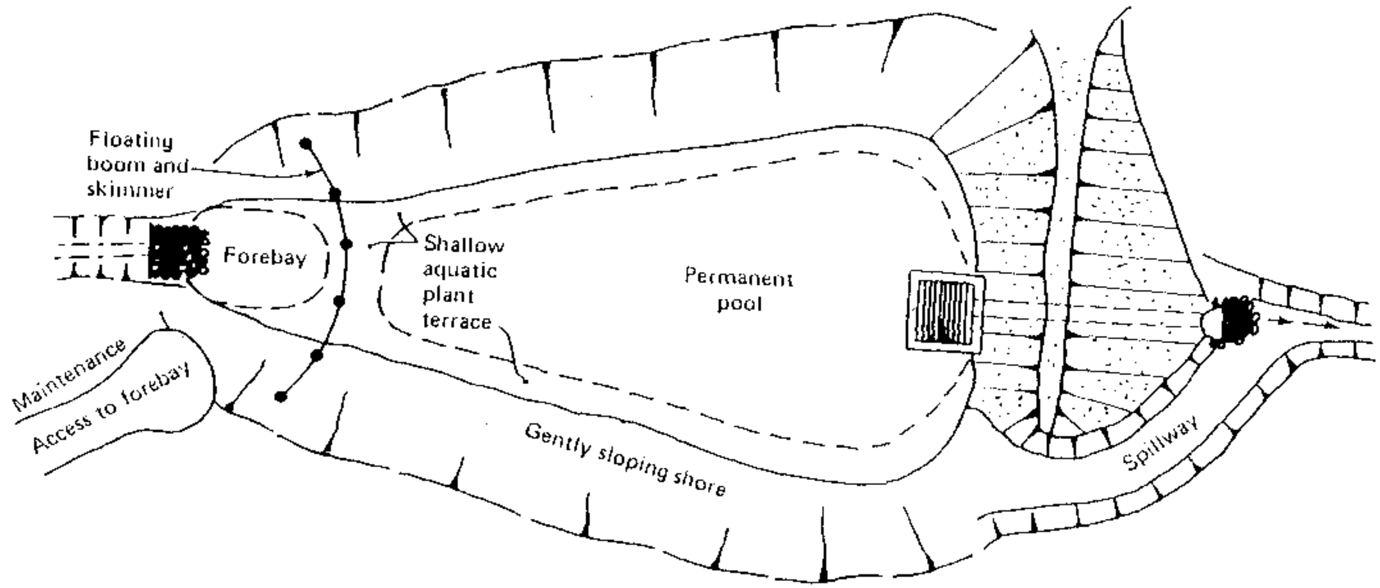
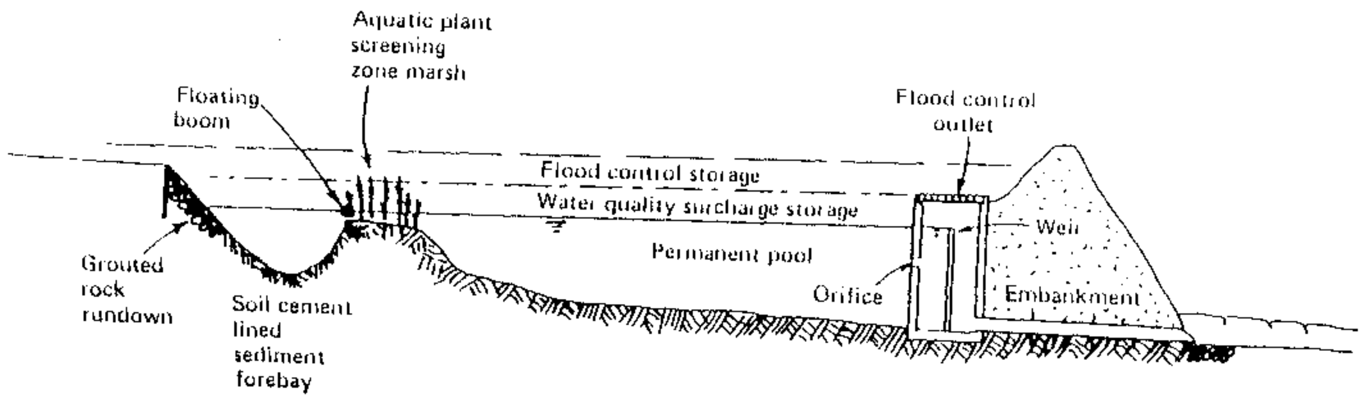
WATSONVILLE SLOUGH SYSTEM
VEGETATED RIPARIAN BUFFERS IRRIGATED WITH RECIRCULATED SLOUGH / TAILWATER DRAINAGE

FIGURE **8 - 5**





QUESTA ENGINEERING, CORPORATION
POINT RICHMOND, CALIFORNIA

WATSONVILLE SLOUGH SYSTEM
CONSTRUCTED WETLANDS / WET POND FOR BEACH ROAD DITCH

FIGURE **8 - 6**

vegetated buffers between the slough channels and the farm fields. The vegetated buffers would serve to intercept and filter runoff irrigation return flow and associated pollutants from agricultural lands, as well as to provide for filtering of sediments and attached pollutants in the sloughs under certain high water conditions. Due to the diffuse sources and routes of surface runoff pollutants, it is not possible to offer pollutant removal estimates for vegetated buffer strips comparable to those provided for the other recommended downstream treatment measures. The effectiveness of buffers depends on their width, slope, vegetation and the dispersal of runoff. Buffer widths of 20 to 30 meters (66 to 99 feet) are commonly used and recommended for agricultural areas. Guidelines should be developed locally by the City and County for vegetated buffers along the sloughs for other types of development.

Figure 8-7 and **8-8** illustrate, in plan view, how these vegetated buffer strips might be implemented; cross-section diagrams are illustrated in **Figure 8-9**. **Figure 8-7** (Option 1) shows the creation of a meandering channel, with vegetated stream side terraces that could support emergent marsh vegetation. **Figure 8-8** (Option 2) shows a more simplified, linear buffer planted with riparian vegetation along the existing edges of the sloughs.

Key Design Features

Key design features and requirements for this water quality/wetland enhancement measure are as summarized below:

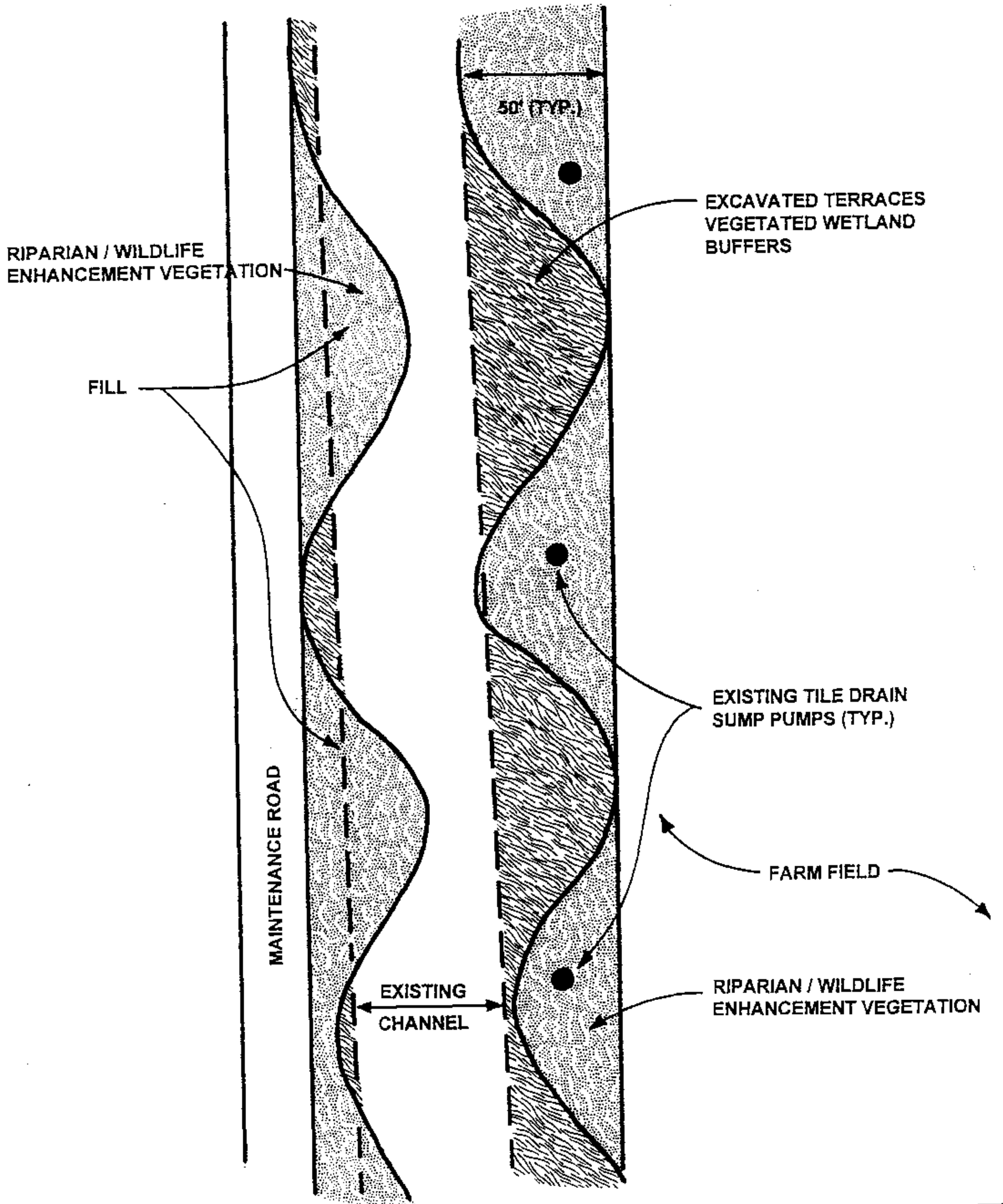
- **Channel Excavation**. Option 1 would involve considerable excavation within the channel to change the configuration to a meandering pattern; Option 2 would be solely a riparian planting project.

- **Drainage Interface**. As diagramed in the various illustrations, key consideration would be avoidance of the existing tile drain sumps which occur every few hundred feet along these reaches of the sloughs. In the case of Option 1, the discharge from these drains could be directed into the terraced vegetated portions of the channel to enhance pollutant removal.

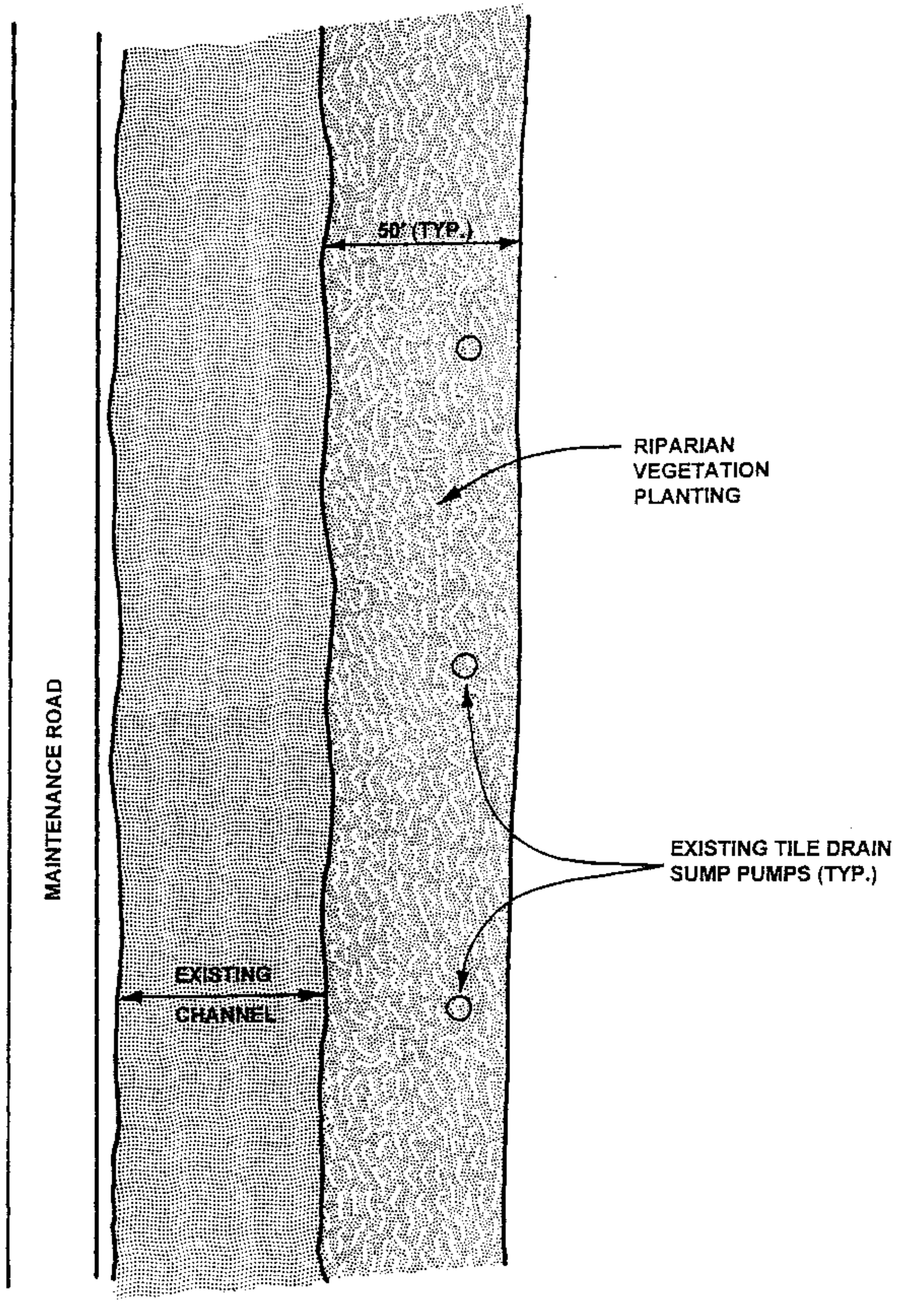
- **Flood Control**. The design of the reconfigured channel should be evaluated to assure maintenance of channel capacity for flood flows at any potentially critical cross-sections.

- **Buffer Width**. As indicated, a 50-plus foot vegetated buffer is recommended as a minimum. Greater widths would improve the enhancement value, but would also require greater dedication of agricultural land and the associated costs.

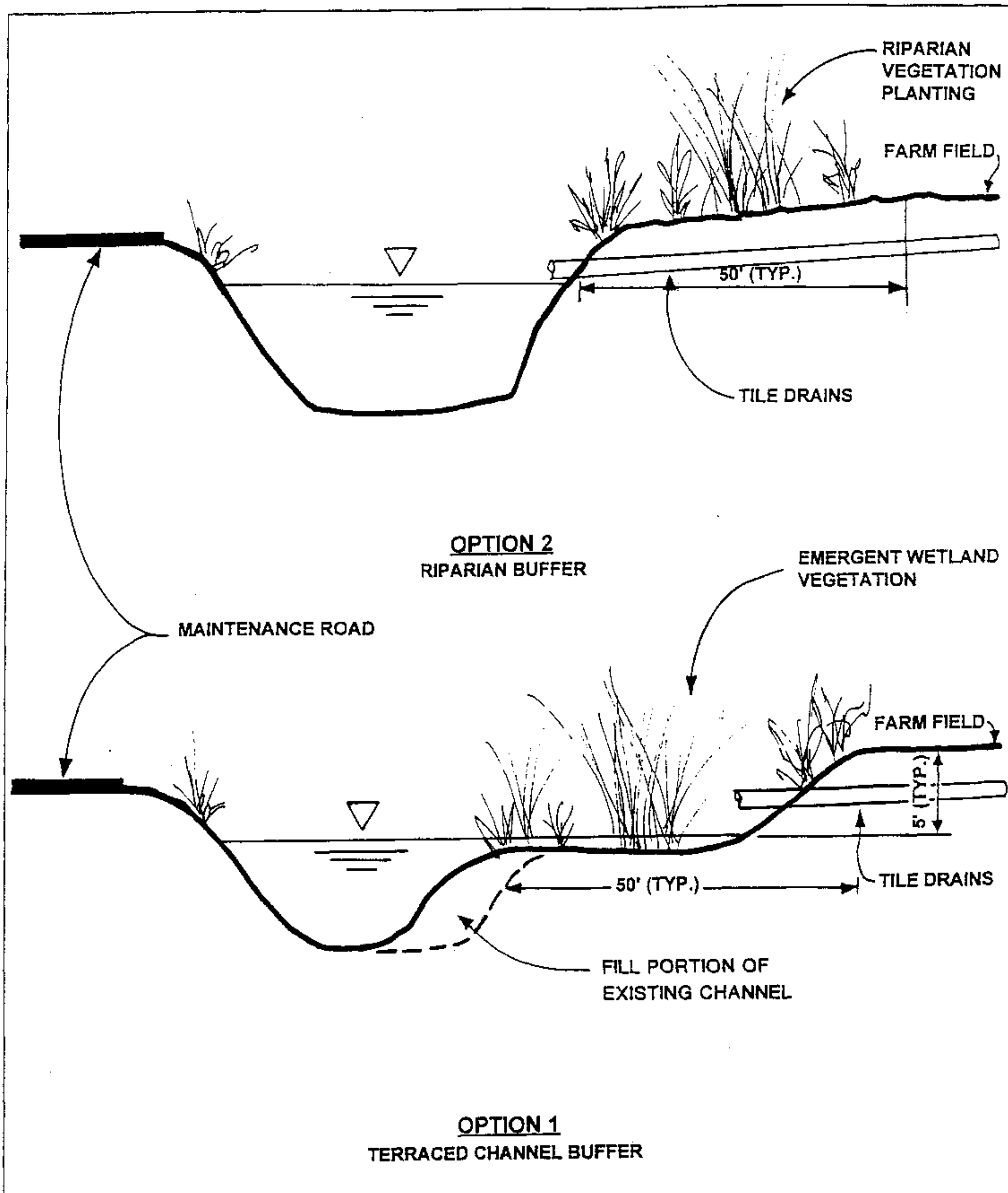
- **Maintenance**. This enhancement measure would be essentially passive, except for the continuous need to remove accumulated sediments from the slough channel for flow capacity. In the diagrams, an access road on one side of the channel is indicated for equipment access. Alternatively, this could be eliminated and both sides of the channel converted to buffer strips if a small suction dredging operation is substituted for the present backhoe/channel method.



QUESTA ENGINEERING, CORPORATION POINT RICHMOND, CALIFORNIA	**WATSONVILLE SLOUGH SYSTEM** VEGETATED BUFFER STRIP ALTERNATIVE #1	FIGURE **8 - 7**



QUESTA ENGINEERING, CORPORATION POINT RICHMOND, CALIFORNIA	WATSONVILLE SLOUGH SYSTEM VEGETATED BUFFER STRIP ALTERNATIVE #2	FIGURE 8 - 8



QUESTA ENGINEERING, CORPORATION POINT RICHMOND, CALIFORNIA	WATSONVILLE SLOUGH SYSTEM VEGETATED BUFFERS TYPICAL CROSS SECTIONS	FIGURE 8 - 9

8.3 COSTS AND IMPLEMENTATION

Provided in **Tables 8-4** through **8-7** are estimated capital and operation and maintenance costs for the three primary types of treatment measures plus the wet detention basin option for beach Road ditch. These costs are preliminary planning level costs and are intended only to provide general indications of probable costs. The cost estimates would need to be revised based on more specific design criteria in the design stage of the implementation. These costs assumed the costs of acquiring the land, construction, and design and administrative costs. Estimate of annual operation and maintenance costs for each measure are also indicated; these are preliminary as well, subject to refinement based upon a specific project design.

Source Control Best Management Practices

Urban. The urban areas of Watsonville contribute urban pollutants such as heavy metals, trash/litter, and oil and grease. Many of the source control BMPs for the urban areas are already in place such sewer maintenance, industrial site controls, and construction site erosion controls. Many of the other BMPs are easily implemented by the adoption of City ordinances or programs. Programs and measures such as providing signage at storm drain inlets and slough areas, formulating and distributing educational literature, and organizing City-wide clean up days are the responsibility of the City. As Watsonville grows in population, future NPDES regulations regarding municipal stormwater runoff quality may mandate some, if not all, of the discussed BMPs to be implemented.

> **Funding**. Funding for urban source control BMPs would likely come directly from the City's budget and/or from developer sponsored mitigation and development fees. Another possible funding source could be a new assessment district specifically designed to enhance and protect the Watsonville Slough system ecosystem.

Agricultural. The agricultural areas contribute sediment, pesticides, and nutrients to the sloughs. The previously identified BMPs for these areas include erosion control, irrigation control, vegetated buffer strips, pesticide management, and fertilizer management. The responsibility of implementing these BMPs is predominately in the hands of the landowner/farmer. Santa Cruz County and the City of Watsonville currently have erosion control ordinances in place; however, these ordinances are generally not applied to agricultural areas and activities. Organizations such as the USDA National Resource Conservation Service (NRCS) formerly, the Soil Conservation Service, Resource Conservation districts, and U.C. Extension play important roles as technical advisors and provide the dissemination of BMP information to the growers.

A farming practices survey prepared for AMBAG in 1993, showed that there are significant differences in the way the erosional control BMPs are viewed and utilized by farmers of different land quality and ethnic groups. Getting farmers to implement integrated pesticide management programs, irrigation control, erosional control, and fertilizer management is a complex issue that must take into account societal, economic, and ethnic values of the farmers and landowners. An erosion control BMP outreach program similar to the one that is currently being implemented by NRCS in the Elkhorn Slough watershed may provide a starting point for farmers in this area to improve their

Table 8-4. Planning Level Cost Estimations for Constructed Wetlands

Assuming 4 acres, @ 5 day residence time	Item Cost	Quantity	Cost
Land	$20,000/acre	4.5	$85,000
Grading and Compaction	$4/cy	4,000 cy	$16,000
Drainage Structures			$15,000
Vegetation Establishment	$5,000/acre	4	$20,000
Subtotal			**$136,000**
Contigencies, Engineering, Admin.	+20%		$27,200
Total			**$163,200**
Yearly Operational and Maintenance Costs (assumes desilting, vegetation and trash management)			**$5,000**

Table 8-5. Planning Level Cost Estimations for Tailwater Circulation

Pump Station	$60,000	1	$60,000
Land	$20,000/acre	10	$200,000
Land	$10,000/acre	10	$100,000
Piping	$20/lf	10,000	$200,000
Vegetation Estabishment	$5,000/acre	13	$65,000
Subtotal			**$625,000**
Contigencies, Engineering, Admin.	+20%		$125,000
Total			**$750,000**
Yearly Operational and Maintenance Costs (assumes pump and piping maintenance, electrical cost pump replacement every 10 years, weekly supervision (8-12 hr.) 1/2 the year)			**$8,500**

Table 8-6. Planning Level Cost Estimations for Vegetated Buffer Strips-Excavation Option

Land	$20,000/acre	20 acres	$400,000
Excavation and Earth Work	$4/cyd	81,000	$324,000
Planting/Vegetation Estabishment	$5,000/acre	20 acres	$100,000
Subtotal			**$824,000**
Contigencies, Engineering, Admin.	+20%		$164,800
Total			**$988,800**
Yearly Operational and Maintenance Costs (assumes desilting, vegetation and trash management at $125/acre/year)			**$2,500**

Note: Non-excavation option would eliminate excavation costs; land costs assume a and complete buffers in the lower Watsonville and Harkins sloughs

Table 8-7. Planning Level Cost Estimations for Wet Pond for the Beach Road Ditch

Land	$20,000/acre	12	$240,000
Excavation and Earth Work	$4/cyd	40,000	$160,000
Planting/Vegetation Est. (fringe planting)	$5,000/acre	4	$20,000
Spillway construction/materials			$15,000
Subtotal			**$435,000**
Contigencies, Engineering, Admin.	+20%		$87,000
Total			**$522,000**
Yearly Operational and Maintenance Costs (assumes desilting, vegetation and trash management)			**$2,500**

farming and erosion control practices as well as educate them about the potential environmental and cost impacts of their current practices.

Implementation of BMP programs in the agricultural areas of the Watsonville Slough system watershed should include some of the seven recommendations stated in the Elkhorn Sloughs farming practices survey report such as (1) contact growers through trusted channels, (2) emphasize in personal contacts, (3) increase communication in Spanish, (4) reduce service bias to growers, (5) provide technical consulting, (6) encourage less technical solutions, and (7) offer low interest loans for the implementation of BMPs.

Funding. The funding of the farmer outreach and information dissemination would likely come from funding sources such AMBAG, USDA, and Santa Cruz County.

Rural Residential. The rural residential land use of the Watsonville slough areas is for the most part a small portion of the slough water quality problems. Rural residential land use impacts water quality mainly from a nutrient and erosion perspective from septic systems and livestock containment areas. Septic systems in these areas are already stringently controlled by existing County regulations. Any time new construction or significant additions are made to a waste disposal system County ordinances and regulations are enforced. Hence, implementation and enforcement for septic system BMPs is already in place. BMPs for livestock containment areas involve proper siting and drainage control. The implementation of these BMPs rests with the landowner, and some cases may be enforceable by current RWQCB regulations.

Funding. Funding for rural residential source control BMPs would be expected to be the responsibility of the landowner.

Downstream Treatment Measures

The implementation responsibility of the treatment measures identified below are likely to be split between the City of Watsonville or the County of Santa Cruz. However, this may not exclude other agencies or a future joint agreement to establish an overseeing agency.

Constructed Wetlands. Constructed wetlands would be beneficial to improving the water quality of the slough system. The possible locations currently slated for this treatment measure are in upper Watsonville Slough both above and below Lee Road. This area starts immediately below the existing wetland upstream of the Harkins Slough Road crossing. Some of this stretch is within the City limits of Watsonville, thus in those locations permit authority, land use designation and regulatory approval would be within the City's jurisdiction. Other sections of this stretch are within County jurisdiction and thus planning and approval would be the responsibility of the county. It is likely that the City and the County would have to take the lead on the implementation of this measure. One potential implementation solution, may include future development. This treatment feature could be incorporated into any proposed project as a mitigation, design amenity or as a condition of approval for the potential development proposed in the area. It may also be used as an offsite wetland mitigation area for other nearby developments (this would have to be approved by state and federal agencies).

Funding. Funding for this feature could come from various sources. It could come from potential developers of the land, or Clean Water Act (CWA) section 319(h) funds for non-point source pollutant projects, with matching or contributory funds by the City of Watsonville, and/or the County of Santa Cruz.

Tailwater Recirculation. In order to implement the tailwater recirculation treatment alternative funding would have to be procured from State or federal agencies to purchase the land and construct project. Implementation would mean that landowners would have to agree to sell their land and maintain proper setback and agricultural practices around the project. It is likely that this treatment measure and management program would comply with the EPA Coastal Non-point Pollution Control Program development and approval guidelines

Funding. Possible grant funding for this feature may be available from the CWA 319(h) funds, Coastal Conservancy Grants, and State Water Resources Control Board grants.

Vegetated Buffers. This BMP involves the reworking and planting of portions of the lower Watsonville and Harkins Sloughs. These channels and the bordering lands are in private ownership and implementation would require purchase and/or dedication of land from these landowners. The County, as the flood control authority, would be the logical implementing agency for this measure.

Funding. The funding for these drainage improvements could come from Flood District Zone 7 assessment, general County funds, grants, and/or mitigation banking.

8.4 RECOMMENDED ACTIONS AND FUTURE STUDIES

Water quality impairment in the Watsonville Slough System has been known to exist for the past 10 to 15 years, based largely on the State Mussel Watch and Toxic Substances Monitoring Program findings. However, the full extent of water problems and their relationship to land use and water management activities in the area had not been studied prior to this project. The review of historic data, combined with additional water quality monitoring in the present study has improved the understanding of the slough system water quality; but, contrary to one of the project goals, it has not produced definitive information on the source(s) of specific water quality conditions (e.g., chronic high ammonia levels in Struve Slough), nor answers to the question of the actual beneficial use impacts of certain constituents that are above standard criteria (e.g., nitrates and several heavy metals). The downstream treatment recommendations outlined above are, in the judgement of the consultant, the best types of measures that can be employed to improve the water quality conditions, while also achieving stated wetland restoration aims and minimizing adverse impacts to other water management interests in the watershed. But these measures can only be viewed as conceptual plans and tentative conclusions, given the lack of information or answers to several key issues. Based on the significant costs and other impacts involved with the implementation of these or other similar measures, it is only prudent that further study be completed in several areas, before a firm decision is reached on implementation of the costly downstream treatment measures recommended by this plan. Also, other less extensive and less costly measures can be taken immediately to address some of the site specific problems in the watershed; this may aid in understanding the overall water quality correcting some specific problems. The recommended actions and additional studies needs are briefly outlined below.

Site Specific Monitoring and Abatement Efforts

Efforts should be continued to apply BMP measures to adjacent and nearby land uses according to the recommendations in **Sections** 7 and **8.1** of this report. As the Monterey Bay Sanctuary's Water Quality Protection Program's components are developed and adopted by the City of Watsonville and Santa Cruz County, and as further studies and monitoring of pollutant sources are undertaken, the information and recommendations of this Plan should be incorporated and adapted into the City's and County's programs. The objective should be to refine and apply those BMP measures that are most effective in eliminating those pollutants identified in the Watsonville Slough System to those areas of the watershed most likely to generate such pollutants.

In order to accomplish this and to identify and abate actual or threatened pollutants discharges adversely affecting the water quality conditions in the sloughs, intensive water quality monitoring and surveillance of various land use activities and operations in the watershed should be undertaken by local officials, citizen volunteers, and/or landowners and business operators. This should be done systematically to cover the potential sources cited in **Section 6.1** of this report, as well as any other sources that may be identified. A joint task force involving the City, County, Coastal Commission, AMBAG and others could be formed and utilized to coordinate and monitor this effort. Where actual, uncontrolled pollution is discovered, it should be reported to the Regional Water Quality Control Board and the Department of Fish and Game, who would initiate enforcement actions where necessary (i.e., cleanup and abatement orders, citations or fines).

Watsonville Slough System Master Plan

Development of a more comprehensive Watsonville Slough System Master Plan should be considered to address resource issues that were not in the scope of this study. Such a master plan would include the determination and mapping of historic wetland extent, wildlife corridors, appropriate wetland buffers, and areas suitable for wetland or upland habitat restoration. Also to be assessed would be areas for potential public acquisition and/or access.

A wetland restoration model should be an element of any slough master plan, and should include information on historic conditions, current constraints (e.g. landowner cooperation), and proven wetland restoration methodologies. An overall master plan would more comprehensively examine the biological, hydrological, and land use attributes of the slough system watershed than does this report, and should derive objectives and recommendations regarding all wetland functions -- water purification, flood water storage, animal and plant habitats and migration corridors, recreation and aesthetics, etc.

The master plan should recommend wetland buffer standards and strategies for maintenance/management and interagency cooperation. While these objectives were not in the scope of this water resources management plan, this plan would serve as the basis for the overall slough system master plan.

AMBAG should reapply for a Clean Water Act Section 205(j) grant to complete this next phase. If a grant is not forthcoming, other funding sources should be pursued. In the interim, individualized restoration efforts, such as those described in this report on Hansons Slough and Harkins Slough (pp. 5-17 - 5-18) should continue and be encouraged.

Water Quality Studies

The following additional water quality studies are recommended to guide the selection of appropriate management practices for water quality improvement:

- **Ammonia**. Study ammonia toxicity thresholds for slough system aquatic species and investigate the sources of chronic elevated ammonia levels in Struve Slough.

- **Metals**. Investigate metals accumulation in slough sediments and aquatic organisms to determine the degree of toxicity and appropriate local objectives for copper, lead, nickel, and zinc. This should be coordinated with the soon-to-be-released toxicity studies being conducted by UCSC.

- **Nitrate Sources and Biostimulation**. Study the relationship between elevated nitrate and phosphate levels (or other biostimulatory factors) and algae production in the slough system; combine this with comprehensive survey of dissolved oxygen and algae blooms in shallow stagnant water zones. Additionally, more intensive sampling should be conducted to pinpoint the sources of the periodic high nitrate concentrations, and to pursue control of these sources as appropriate.

- **Pesticides**. Continue SMW and TSMP tissue analysis and correlate findings with sediment concentration data. This should also be coordinated with the soon-to-be released toxicity studies being conducted by UCSC.

- **Coliform**. Coliform data should continue to be collected by the County and follow-up site investigations should be made to identify and address the sources where repeated high readings (e.g., 1,000 MPN/100 ml or greater) are observed.

Flow Augmentation.

Studies should be continued regarding the potential for flow augmentation in the slough system during the low flow periods. This should consider reclaimed wastewater from the City of Watsonville as one source and also potential augmentation in connection with the PVWMA diversion/aquifer recharge project. The studies should evaluate such factors as volumes and timing of water, the associated water quality, potential release points in the slough system and downstream water quality effects(e.g. depressed salinity) in the estuary. There may be competing uses for this supplemental or reclaimed water (i.e., for direct crop irrigation) which will also have to be considered, and may make this option more costly or difficult to implement.

Recommended Drainage Operation and Maintenance Practices

Better records should be maintained of water levels in the slough system, operation of the pump system, dredging and other operations. Staff gages and/or water level recorders and pump meters should be installed and read regularly. Improved management of pumping regimes and water level controls could be implemented in addition to, or instead of, flow augmentation. The possibility of installing gated culverts at road crossing (e.g. Lee Road., Harkins Slough Road., Walker Street) should be explored as a means of allowing for greater human control over water levels in different portions of the slough system (e.g. intentional impoundment of water to increase the hydroperiod for certain wetland areas, etc).

8.5 IMPLEMENTATION

The agency and stakeholder members of the Technical Advisory Committee should continue to meet as the Watsonville Sloughs Management Task Force to guide implementation of the Water Resources Management Plan and develop other efforts towards the potential future preparation of a comprehensive Watsonville Slough System Master Plan. Participating agencies should provide staff time for projects within their jurisdiction. Activities of the Task Force would include the following:

<u>Water Resources Plan Implementation</u> - Prioritize and oversee implementation of this plan's recommendations for site specific abatement efforts, water quality studies and additional coordinated monitoring, and flow management and augmentation studies.

<u>Wetland Management/Restoration Plan and Objectives</u> - Refine the recommendations of this plan into more specific overall objectives for water resources management; Develop specific plans for wetland ecosystem protection and restoration throughout the slough system watershed, taking into account existing land uses and watershed activities; and subsequently implement these objectives and plans.

<u>Evaluation and Implementation of BMPs and Protection Policies</u> - Many of the source control BMPs are already being implemented by the County, City and landowners. The effectiveness and degree of implementation should be evaluated and augmented as needed. The following documents should be reviewed for adequacy with respect to protection of the slough system: city and county general plans, land development ordinances, and design criteria; the Monterey Bay National Marine Sanctuary's Water Quality Protection Plan; and the Central Coast Regional Water Quality Control Board's Basin Plan provisions.

<u>Implementation and Funding Mechanisms</u> - The task force should seek to identify and coordinate various funding mechanisms for this plan's implementation such as: state and federal grants and loans, drainage (stormwater district) fees, private grant funding, use of conservation easements, and mitigation measures for new development. The task force should also explore potential funding sources for a Watsonville Slough System Master Plan. While an overall master plan would ease coordination of comprehensive slough system resource management, it is not a prerequisite for the implementation activities listed above.

SECTION 9

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APPENDIX A

USLE CALCULATIONS

Table 1: USLE Calculations
Gallighans Slough

Land Use	Slope	Cover Conditions	Erodibility (K)	Length Slope	Erosion Rate (Tons/Acre)	Total Area (Acres)	Sediment Loss (Tons/Year)
Grain	steep	Fields	0.32	6.05	8.7	13.8	120.2
Bushberries	moderate	Fields	0.32	3.13	4.5	64.5	290.8
Bushberries	steep	Fields	0.15	8.52	5.8	12.1	69.6
Bushberries	steep	Roads/Ditches	0.15	8.52	57.5	2.1	120.8
Strawberries	gentle	Fields	0.32	1	1.4	21.8	31.4
Strawberries	moderate	Fields	0.32	2.03	2.9	3.8	11.1
Strawberries	mod.steep	Fields	0.32	4.2	6.1	49.2	297.7
Strawberries	mod.steep	Roads/Ditches	0.32	4.2	60.5	8.7	526.4
Strawberries	steep	Fields	0.32	9.56	13.8	34.4	473.7
Strawberries	steep	Roads/Ditches	0.32	9.56	137.7	6.1	840.0
Strawberries	moderate	Fields	0.15	3.1	2.1	5.2	10.9
Strawberries	steep	Fields	0.15	5.28	3.6	13.4	47.8
Strawberries	steep	Roads/Ditches	0.15	5.28	35.6	2.4	85.4
Flowers	gentle	Fields	0.32	0.38	1.8	19.1	35.0
Flowers	gentle	Fields	0.32	0.17	4.1	8.1	33.0
Other Row Crops	moderate	Fields	0.32	1.85	2.7	85.1	226.7
Native Vegetation	moderate	Open space	0.32	2.29	0.4	64.3	23.5
Native Vegetation	mod.steep	Open space	0.32	3.14	0.5	379.7	190.6
Native Vegetation	steep	Open space	0.32	4.02	0.6	119.9	77.1
Native Vegetation	moderate	Open space	0.15	4.41	0.3	187.8	58.2
Native Vegetation	steep	Open space	0.15	9.55	0.7	225.5	161.5
				Total Annual Sediment Loss (Tons/Year)			**3731.2**

Table 2: USLE Calculations
Harkins Slough

Land Use	Slope	Cover Conditions	Erodibility (K)	Length Slope	Erosion Rate (Tons/Acre)	Total Area (Acres)	Sediment Loss (Tons/Year)
Grain	moderate	Fields	0.15	3.34	2.3	108.1	243.4
Grain	steep	Fields	0.32	4.3	6.2	8.5	52.7
Bushberries	moderate	Fields	0.32	2.09	3.0	30.4	91.4
Bushberries	moderate	Fields	0.17	2.34	1.8	19.0	34.0
Strawberries	gent./mod.	Fields	0.15	2.33	1.6	229.5	360.3
Strawberries	moderate	Fields	0.15	4.06	2.7	129.7	355.4
Strawberries	moderate	Roads/Ditches	0.15	4.06	27.4	22.9	627.5
Strawberries	mod.steep	Fields	0.15	6.74	4.6	54.5	248.0
Strawberries	mod.steep	Roads/Ditches	0.15	6.74	45.5	9.6	436.8
Strawberries	steep	Fields	0.15	10.4	7.0	11.7	82.1
Strawberries	steep	Roads/Ditches	0.15	10.4	70.2	2.1	145.3
Strawberries	gen/mod.	Fields	0.17	1.72	1.3	16.1	21.3
Strawberries	moderate	Fields	0.17	3.5	2.7	19.0	51.3
Strawberries	gentle	Fields	0.28	0.22	0.3	10.9	3.1
Strawberries	gentle	Fields	0.32	1	1.4	21.3	30.7
Strawberries	moderate	Fields	0.32	1.85	2.7	20.5	54.5
Strawberries	mod.steep	Fields	0.32	3.51	5.1	8.5	42.9
Strawberries	mod.steep	Roads/Ditches	0.32	3.51	50.5	1.5	75.8
Flowers	gentle	Fields	0.17	0.17	0.1	3.3	0.4
Flowers	steep	Fields	0.17	10.42	8.0	10.6	84.5
Flowers	gentle	Fields	0.32	1.78	2.6	4.7	12.2
Other Row Crops	gentle	Fields	0.24	0.08	0.1	219.4	18.9
Orchards	steep	Fields	0.17	8.52	6.5	10.9	70.9
Orchards	gentle	Fields	0.28	0.98	1.2	22.0	26.4
Orchards	moderate	Fields	0.32	1.72	2.5	44.1	110.3
Pasture	gentle	Open space	0.15	2.12	1.6	21.3	33.9
Native Vegetation	steep	Open space	0.15	9.88	0.7	179.3	125.5
Native Vegetation	moderate	Open space	0.17	3.99	0.3	219.7	74.7
Native Vegetation	steep	Open space	0.17	8.12	0.7	1132.9	793.0
Native Vegetation	gentle	Open space	0.24	0.27	0.0	235.3	7.5
Native Vegetation	gentle	Open space	0.28	0.51	0.1	32.3	2.3
Native Vegetation	moderate	Open space	0.32	5.51	0.9	435.6	384.2
Native Vegetation	mod.steep	Open space	0.32	6.31	1.0	734.4	734.4
Native Vegetation	steep	Open space	0.32	7.92	1.3	872.0	1107.4
				Total Annual Sediment Loss (Tons/Year)			**6542.7**

Table 3: USLE Calculations
Hanson Slough

Land Use	Slope	Cover Conditions	Erodibility (K)	Length Slope	Erosion Rate (Tons/Acre)	Total Area (Acres)	Sediment Loss (Tons/Year)
Strawberries	gentle	Fields	0.28	0.51	0.6	12.3	7.9
Strawberries	moderate	Fields	0.28	1.43	1.8	22.3	40.1
Pasture	gentle	Open space	0.32	0.6	1.0	27.0	26.0
Orchards	gentle	Fields	0.24	0.47	0.5	84.0	42.7
Orchards	moderate	Fields	0.28	2.6	3.3	27.0	88.6
Native Vegetation	moderate	Open space	0.24	2.7	0.1	151.1	13.9
Native Vegetation	gent/mod.	Open space	0.28	2.11	0.3	38.5	10.4
Native Vegetation	gentle	Open space	0.32	0.23	0.0	21.1	0.7
				Total Annual Sediment Loss (Tons/Year)			**230.3**

Table 4: USLE Calculations
West Branch Slough

Land Use	Slope	Cover Conditions	Erodibility (K)	Length Slope	Erosion Rate (Tons/Acre)	Total Area (Acres)	Sediment Loss (Tons/Year)
Strawberries	gentle	Fields	0.24	1	1.1	16.1	17.4
Strawberries	moderate	Fields	0.24	2.21	2.4	13.8	33.0
Strawberries	moderate	Roads/Ditches	0.24	2.21	23.9	2.4	57.4
Native Vegetation	gentle	Open space	0.24	0.6	0.1	84.3	6.1
Native Vegetation	moderate	Open space	0.24	2.64	0.3	168.5	53.4
Native Vegetation	moderate	Open space	0.32	1.85	0.3	48.9	14.5
				Total Annual Sediment Loss (Tons/Year)			**181.7**

Table 5: USLE Calculations
Struve Slough

Land Use	Slope	Cover Conditions	Erodibility (K)	Length Slope	Erosion Rate (Tons/Acre)	Total Area (Acres)	Sediment Loss (Tons/Year)
Bushberries	moderate	Fields	0.24	1.48	1.6	15.7	25.0
Orchards	moderate	Fields	0.24	1.5	1.6	17.6	28.5
Other Row Crops	gentle	Fields	0.24	0.12	0.1	29.0	3.8
Native Vegetation	gentle	Open space	0.24	0.18	0.0	150.8	3.3
Native Vegetation	mod.steep	Open space	0.24	3.31	0.4	101.9	40.8
				Total Annual Sediment Loss (Tons/Year)			**101.4**

Table 6: USLE Calculations
Watsonville Slough

Land Use	Slope	Cover Conditions	Erodibility (K)	Length Slope	Erosion Rate (Tons/Acre)	Total Area (Acres)	Sediment Loss (Tons/Year)
Strawberries	gentle	Fields	0.15	1.78	1.2	9.9	11.9
Strawberries	mod.steep	Fields	0.15	3.89	2.6	42.4	111.5
Strawberries	mod.steep	Roads/Ditches	0.15	3.89	26.3	7.5	197.3
Strawberries	steep	Fields	0.15	7.62	5.5	26.9	147.1
Strawberries	steep	Roads/Ditches	0.15	7.62	51.4	3.5	179.9
Pasture	mod.steep	Open space	0.15	3.33	0.2	44.1	10.9
Pasture	gentle	Open space	0.24	0.4	0.0	29.4	1.4
Other Row Crops	gentle	Fields	0.24	0.05	0.1	1216.8	65.7
Orchards	gentle	Fields	0.32	0.55	0.8	26.1	20.7
Bushberries	gentle	Fields	0.32	0.42	0.6	16.6	10.0
Native Vegetation	gentle	Open space	0.24	0.37	0.0	54.1	2.6
Native Vegetation	gentle	Open space	0.32	0.26	0.0	163.3	6.9
				Total Annual Sediment Loss (Tons/Year)			**765.9**

Table A-1: LS Values

SLOPE LENGTH IN FEET

Percent Slope	25	50	75	100	125	150	200	250	300	350	400	450	500	550	600	700	800	1000	1200
0.5	0.07	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.16
1.0	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.17	0.10	0.19	0.20	0.20	0.21	0.22	0.22	0.23	0.24	0.26	0.27
2.0	0.13	0.16	0.10	0.20	0.21	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.33	0.34	0.36	0.37	0.40	0.42
3.0	0.19	0.23	0.26	0.29	0.31	0.32	0.35	0.30	0.40	0.42	0.43	0.45	0.46	0.48	0.49	0.51	0.54	0.57	0.60
4.0	0.23	0.30	0.36	0.40	0.44	0.47	0.53	0.58	0.62	0.66	0.70	0.73	0.76	0.79	0.82	0.87	0.92	1.00	1.08
5.0	0.27	0.38	0.46	0.53	0.60	0.65	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.25	1.31	1.41	1.51	1.69	1.85
6.0	0.34	0.47	0.58	0.67	0.75	0.82	0.95	1.06	1.16	1.26	1.34	1.42	1.50	1.57	1.65	1.78	1.90	2.12	2.33
7.0	0.41	0.50	0.71	0.82	0.92	1.01	1.16	1.30	1.43	1.54	1.65	1.75	1.84	1.93	2.02	2.18	2.33	2.60	2.85
8.0	0.49	0.70	0.86	0.99	1.11	1.21	1.40	1.56	1.71	1.85	1.98	2.10	2.21	2.32	2.42	2.62	2.80	3.13	3.43
9.0	0.59	0.83	1.01	1.17	1.31	1.43	1.66	1.85	2.03	2.19	2.34	2.40	2.62	2.75	2.87	3.10	3.31	3.70	4.06
10.0	0.68	0.96	1.17	1.35	1.51	1.66	1.92	2.14	2.35	2.53	2.71	2.87	3.03	3.10	3.32	3.50	3.83	4.28	4.69
12.0	0.87	1.23	1.51	1.74	1.95	2.13	2.46	2.75	3.02	3.26	3.40	3.69	3.89	4.08	4.27	4.61	4.93	5.51	6.03
14.0	1.08	1.52	1.86	2.15	2.40	2.63	3.04	3.40	3.73	4.02	4.30	4.56	4.81	5.04	5.27	5.69	6.08	6.00	7.45
16.0	1.29	1.82	2.23	2.58	2.88	3.16	3.65	4.08	4.47	4.82	5.16	5.47	5.77	6.05	6.32	6.82	7.29	8.15	8.93
18.0	1.51	2.14	2.62	3.02	3.38	3.70	4.27	4.78	5.23	5.65	6.04	6.41	6.76	7.09	7.40	7.99	8.55	9.56	10.5
20.0	1.74	2.46	3.01	3.48	3.89	4.26	4.92	5.50	6.02	6.51	6.96	7.38	7.78	8.16	8.52	9.20	9.84	11.0	12.0
22.0	1.97	2.79	3.42	3.94	4.41	4.83	5.58	6.24	6.83	7.38	7.89	8.37	8.82	9.25	9.66	10.4	11.2	12.S	13.7
24.0	2.21	3.12	3.83	4.42	4.94	5.41	6.25	6.99	7.65	8.26	8.84	9.37	9.88	10.4	10.8	11.7	12.5	14.0	15.3
26.0	2.45	3.46	4.24	4.90	5.48	6.00	6.93	7.74	8.48	9.16	9.80	10.4	11.0	11.5	12.0	13.0	13.9	15.5	17.0
28.0	2.69	3.81	4.66	5.38	6.02	6.59	7.61	8.51	9.32	10.1	10.8	11.4	12.0	12.6	13.2	14.2	15.2	17.0	18.6
30.0	2.93	4.15	5.08	5.87	6.56	7.19	8.30	9.28	10.2	11.0	11.7	12.4	13.1	13.8	14.4	15.5	16.6	18.6	20.3
32.0	3.18	4.49	5.50	6.35	7.10	7.78	8.99	10.0	11.0	11.9	12.7	13.5	14.2	14.9	15.6	16.8	18.0	20.1	22.0
34.0	3.42	4.84	5.92	6.84	7.65	8.38	9.67	10.8	11.8	12.8	13.7	14.5	15.3	16.0	16.8	18.1	19.3	21.6	23.7
36.0	3.66	5.18	6.34	7.32	8.18	8.97	10.4	11.6	12.7	13.7	14.6	15.5	16.4	17.2	17.9	19.4	20.7	23.2	25.4
38.0	3.90	5.52	6.75	7.80	8.72	9.55	11.0	12.3	13.5	14.6	15.6	16.5	17.4	18.3	19.1	20.6	22.1	24.7	27.0
40.0	4.14	5.85	7.16	8.27	9.25	10.1	11.7	13.1	14.3	15.5	16.5	17.5	18.5	19.4	20.3	21.9	23.4	26.2	28.7
45.0	4.71	6.67	8.17	9.43	10.5	11.5	13.3	14.9	16.3	17.6	18.9	20.0	21.1	22.1	23.1	24.9	26.7	29.8	32.7
50.0	5.27	7.45	9.12	10.5	11.8	12.9	14.9	16.7	18.2	19.7	21.1	22.3	23.6	24.7	25.8	27.9	29.8	33.3	36.5
55.0	5.79	8.10	10.0	11.6	12.9	14.2	16.4	18.3	20.0	21.7	23.1	24.6	25.9	27.1	28.4	30.6	32.7	36.6	40.1
60.0	6.27	8.87	10.9	12.5	14.0	15.4	17.7	1?.8	21.7	23.5	25.1	26.6	28.1	29.4	30.7	33.2	35.5	39.7	43.5

APPENDIX B

WATER QUALITY/WETLANDS POLICIES

I. LOCAL POLICIES & ORDINANCES REGARDING POLLUTED RUNOFF AND WETLAND HABITAT

A. Santa Cruz County

1. 1993 Santa Cruz County General Plan and Local Coastal Plan

The Santa Cruz County 1993 General Plan and the incorporated Local Coastal Program (LCP) includes broad policies that are intended to set the framework for environmental review within the County. The environmental review policies are as follows:

- Require environmental review per California Environmental Quality Act (CEQA) guidelines of all new development projects, rezoning, and General Plan Amendments
- Require mitigation measures as identified through the Environmental Review process to be incorporated into all approved development projects, or require adoption of overriding considerations
- Review appropriate projects outside the Coastal Zone for Coastal Zone impacts in conformance with the California Coastal Act (per public Resources Code Sec. 30200).

The programs carried out by the County are to review and comment on Environmental Impact Reports (EIRs) of other jurisdictions which affect the County and to maintain and update the adopted Environmental Guidelines to define and regulate the County's environmental review process in compliance with CEQA.

Definition of Wetland Resources:

The General Plan designates and defines wetlands as transitional areas between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. Examples of wetlands are saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens (e.g. wetlands with emergent vegetation).

Regarding wetland resources, the overall goals of the County are to protect and restore unique, rare, threatened, endangered and other natural and cultural resources that warrant preservation because of their biological value, scarcity, scientific value, aesthetic quality or cultural significance. Wetlands, lakes, estuaries, lagoons, streams, riparian corridors, and rivers are defined as sensitive habitats. The objective for protecting riparian corridors and wetlands is to preserve, protect, and restore all riparian corridors and wetlands for the protection of wildlife and aquatic habitat, water quality, erosion control, open space, aesthetic and recreational values and the conveyance and storage of flood waters.

Policies Regarding Wetland Resources

Specific policies regarding wetland resources in the General Plan are as follows:

- Implement the protection of riparian corridors and wetlands through the Riparian Corridor and Wetland Protection Ordinance.
- Development activities, land alteration, and vegetation disturbance within riparian corridors and wetlands and required buffers shall be prohibited unless an exception is granted per the Riparian Corridor and Wetlands Protection Ordinance
- Prohibit development within the 100 foot riparian corridor of all wetlands. Exceptions are allowed only where consistent with the Riparian Corridor and Wetlands Protection Ordinance, and in all cases, maximize distance between proposed structures and wetlands. Require measures to prevent water quality degradation from adjacent land uses, as outlined in the Water Resources section of the General Plan
- Exclude land within riparian corridors in the calculation of development density or net parcel size. Grant full density

credit for the portion of the property outside the riparian corridor which is within the required buffer setback, excluding areas over 30% slope, up to a maximum of 50% of the total area of the property which is outside the riparian corridor

- Allow compatible uses in and adjacent to riparian corridors that do not impair or degrade the riparian plant and animal systems, or water supply values, such as non-motorized recreation and pedestrian trails, parks, interpretive facilities and fishing facilities. Allow development in these areas only in conjunction with approval of a riparian exception.

- Require environmental review of all proposed development projects affecting riparian corridors or wetland and preparation of an EIR or Biotic Report for projects which may have a significant effect on the corridors or wetlands

- Require development in or adjacent to wetlands to incorporate the recommendations of a management plan which evaluates: migratory waterfowl use December 1 to April 30; compatibility of agricultural use and biotic and water quality protection; and the protection of adjoining uplands

- Require development projects in wetland drainage basins to include drainage facilities which will maintain surface runoff patterns and minimize erosion and introduction of pollutants

2. Santa Cruz County Riparian Corridor and Wetlands Protection Ordinance

The purpose of the ordinance is to eliminate or minimize any development activities in the riparian corridor in order to preserve, protect, and restore riparian corridors. No development is allowed within the riparian corridor other than those allowed through exemptions and exceptions. The following activities are exempt:

- The continuance of any preexisting nonagricultural use, provided such use has not lapsed for a period of one year or more. This includes change of uses which do not significantly increase the degree of encroachment into or impact on the riparian corridor as determined by the Planning Director

- The continuance of any preexisting agricultural use, provided such use has been exercised within the last five years

- All activities done pursuant to a valid County timber harvest permit

- All activities listed in the California Food and Agricultural Code pursuant to the control or eradication of a pest as defined in Section 5006, Food and Agriculture Code, as required or authorized by the County Agricultural Commissioner

- Drainage, erosion control, or habitat restoration measures required as a condition of County approval of a permitted project

Exceptions to the Riparian Corridor and Wetlands Protection Ordinance are considered by application and subject to the following findings:

- That there are special circumstances or conditions affecting the property;

- That the exception is necessary for the proper design and function of some permitted or existing activity on the property;

- That the granting of the exception will not be detrimental to the public welfare or injurious to other property downstream or in the area in which the project is located;

- That the granting of the exception, in the Coastal Zone, will not reduce or adversely impact the riparian corridor, and there is no feasible less environmentally damaging alternative;

- That the granting of the exception is in accordance with the purpose of the ordinance, and with the objectives of the General Plan and elements thereof, and the Local Coastal Program Land Use Plan;

3. Santa Cruz County Erosion Control Ordinance

The purpose of the Erosion Control Ordinance is to eliminate and prevent conditions of accelerated erosion that either have led to or could lead to degradation of water quality, loss of fish habitat, damage to property, loss of topsoil and vegetation cover, disruption of water supply, and increased danger from flooding, and to implement Local Coastal Program land use policies.

The policies in the ordinance that are intended to protect wetland resources is as follows:

- Streams or drainage courses shall not be obstructed or disturbed except for approved road crossings, unless disturbance of a drainage course will improve overall site design and be consistent with the purpose of the ordinance;
- Erosion control measures specified in, or pursuant to, this ordinance, shall be in place and maintained at all time between October 15 and April 15;
- Runoff from activities subject to a building permit, land division permit, or development permit shall be properly controlled to prevent erosion;
- Land clearing shall be kept to a minimum and vegetation removal shall be limited to that amount necessary for building, access, and construction;

The provisions for land clearing when no land development permit has been issued requiring an erosion control plan is as follows:

- Any amount of clearing in a sensitive habitat;
- One-quarter acre or more of clearing in the Coastal Zone if also in a least-disturbed watershed, a water supply watershed, or an area of high erosion hazard;
- One acre or more of clearing in all areas not included in the above items;

When a land development permit has been issued, land clearing may be done according to the approved development plan; however, approval of land clearing shall meet the following conditions. All disturbed surfaces shall be prepared and maintained to control erosion and to establish native or naturalized vegetative growth compatible with the area. Control shall consist of the following:

- Effective temporary planting and mulching with straw and/or some other slope stabilization material;
- Permanent planting of native or naturalized drought resistant species of shrubs, trees, etc., pursuant to the County's Landscape Criteria, when the project is completed;
- Mulching, fertilizing, watering or other methods may be required to establish new vegetation. On slopes less than 20%, topsoil should be stockpiled and reapplied;

4. Santa Cruz County *Sensitive* Habitat Protection Ordinance

The purposes of this ordinance are to minimize the disturbance of biotic communities which are rare or especially valuable because of their special nature or role in an ecosystem, and which could be easily disturbed or degraded by human activity; to protect and preserve these biotic resources for their genetic, scientific, and educational values; and to implement policies of the General Plan and the Local Coastal Program Land Use Plan. Lakes, wetlands, estuaries, lagoons, streams, rivers and riparian corridors are among the habitats considered sensitive. Sensitive habitat policies include the following:

- No toxic chemical substance shall be used in such a way as to have deleterious effects on the habitat unless an emergency has been declared, or such use has been deemed necessary by the California Department of Fish and Game to eliminate or reduce a threat to the habitat itself, or a substantial risk to public health will exist if the toxic chemical substance is not used;

- The Agricultural Commissioner, when reviewing an application to use a restricted material, shall consider the potential effects of the material on a sensitive habitat, and mitigation measures shall be required as necessary to protect the habitat. No approval shall be issued if adverse impacts cannot be mitigated;

- A biotic assessment shall be required for all development activities and applications in areas of biotic concern;

- No development activity shall commence in an area of biotic concern until a biotic approval has been issued unless such activity has been reviewed for biotic concerns concurrently with the review of a development or land-division application;

The following conditions shall be applied to all development within any sensitive habitat area:

- All development shall mitigate significant environmental impacts, as determined by the Environmental Coordinator;

- Dedication of an open space or conservation easement or an equivalent measure shall be required as necessary to protect the portion of a sensitive habitat which is undisturbed by the proposed development activity or to protect a sensitive habitat on an adjacent parcel;

- Restoration of any area which is a degraded sensitive habitat or has caused or is causing the degradation of a sensitive habitat shall be required, provided that any restoration required shall be commensurate with the scale of the proposed development;

Only resource-dependent uses shall be allowed within any environmentally sensitive habitat area. All development activities in or adjacent to wetlands shall conform to the following list of permitted activities.

Type of Sensitive Area	Permitted or Discretionary Uses	Conditions
All Essential Habitats	nature study and research, hunting, fishing and equestrian trails that have no adverse impacts on the species or habitat	Preservation of essential habitats shall be required
Wetlands, Estuaries, and Lagoons	educational instruction, scientific research, managed nature observation, wetland restoration maintenance to existing public utilities, aquaculture, recreational fishing subject to DFG regulations	One hundred foot buffer measured from the high water mark shall be required Distance between structures and wetlandshall be minimized
Intermittent Wetlands	limited grazing, uses within wetlands, existing agriculture	

No new development shall be allowed adjacent to marshes, streams, and bodies of water if such development would cause adverse impacts on water quality which cannot be mitigated or will not be fully mitigated by the project proponent.

Development that has received a riparian exception approved according to the provision of the Riparian Corridor and Wetlands Protection Ordinance may be exempted from the provisions of this ordinance if the Planning Director has determined that the development activity has received a review equivalent to the review that would be required by the Sensitive Habitat Protection Ordinance.

B. City of Watsonville

1. Watsonville 2005 General Plan

The goals for environmental resource management outlined in the General Plan are established to preserve the natural resources of the Planning Area. The goals provide for open space, conservation, and limitations on the extent of future urbanization. No specific goals are identified for protecting wetland resources, however; one goal is to identify and protect the natural resources of the Watsonville Planning Area and another is to preserve and protect the remaining areas of wildlife habitat for their scenic and scientific value.

Land that is designated Environmental Management is set aside for the protection and preservation of natural resources such as wetlands, sloughs, wildlife habitat, and mineral and archaeological resources. Development is limited to that necessary to support the protection and preservation of these areas and resources. Allowed development is determined based on the appropriateness of the location, accessibility, traffic impacts, existing site conditions, design compatibility with adjacent land uses, natural and built constraints, and community impacts.

Policies Regarding Wetland Resources:

- The City shall use planning measures to restrict urban development in environmentally sensitive areas;
- The City shall require landscape restoration with native plants from regional seed stocks on sites disturbed by urban development;
- When necessary and possible, the City shall purchase lands for open space uses including wildland preservation, parks, environmental safety, and scenic corridor preservation;
- The City shall cooperate with the County in preparing a biological study for protection of the sloughs and habitat dependent on the sloughs located in and around Watsonville. A plant inventory and map of sensitive biological and botanical resources should be a part of the study;
- The City Council shall consider approving an Open Space Acquisition Plan within two years of the adoption of *Watsonville 2005*. The goal of the plan is to protect and manage wetlands, wetland-associated uplands, sensitive habitats, grasslands, and other environmentally sensitive habitats and agricultural lands. The plan shall evaluate acquisition priorities based on resource values, degree of threat, and availability. The plan shall explore and, where feasible, implement such means as public and private loans and grants, open space district, transferable density credits, dedications from property owners, purchase/leasebacks of agricultural lands, developer fees, and city funds to protect environmentally sensitive and agricultural lands;

- The City shall designate and zone environmentally sensitive areas as EM-OS (Environmental Management-Open Space) to prohibit urban development and to preserve natural resources;

- The City shall require implementation of environmental mitigations on projects that may destroy or impair the future use or existence of natural resources;

- The City shall abide by the provisions of the *Watsonville Local Coastal Plan* and *Watsonville Local Coastal Plan Implementation Ordinance* in the review of proposed development on Coastal Zone lands;

- The City shall conduct an appropriate environmental review process and require that proposed projects adjacent to surrounding, or containing, wetlands be subject to a site-specific analysis which will determine the appropriate size and configuration of areas to buffer wetlands from urban development;

- Where drainage from developments involves discharge into sloughs or wetlands, grease, sediment traps, or other protection measures shall be required. Mitigation monitoring shall be required and enforced by the City to ensure performance as appropriate;

- The City shall require that new construction on slopes leading toward sloughs and wetlands, maintain an undisturbed protective buffer between all cut and fill slopes and the riparian zone;

- Impacts to important wildlife habitat areas shall be identified as part of the City's development review and environmental review processes, and appropriate mitigations shall be considered. Lands within the urban limit line that provide important wildlife habitat include riparian corridors, fresh water marshes, sloughs, woodlands, and steep slopes;

- The City shall support and encourage public and private efforts to restore degraded natural habitat zones and, when possible, to acquire them for preservation;

- The City shall carefully regulate and monitor, within the limits of its authority, the use of pesticides, herbicides, and fungicides in and adjacent to wildlife habitat zones;

- The City shall refer development proposals to the California Department of Fish and Game for its recommendations on conservation measures for native plant communities, riparian vegetation, wildlife habitat, and wetland preservation;

2. City of Watsonville Local Coastal Program - Land-Use Plan 1982

City of Watsonville's LCP defines wetlands using Cowardin et al (1979) as a guide relying essentially on the presence of hydrophytic vegetation, periodic saturation or hydric soils to identify wetlands. The LCP defines environmentally sensitive areas to include but not limited to freshwater wetlands, wetland-upland transition, and riparian habitats.

> "Environmentally sensitive areas" means any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem which could be easily disturbed or degraded by human activities and developments, including endangered species habitat as identified by the State Department of Fish and Game, or by a qualified professional botanist; all coastal wetlands and lagoons and areas of riparian vegetation (City of Watsonville 1982).

Policies Regarding Wetland Resources:

- Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on such resource shall be allowed within such areas;

- Development of areas adjacent to environmentally sensitive habitat areas shall be sited and designed so as to prevent impacts which would significantly degrade or be incompatible with the continuance of such habitat areas;

- The biological productivity of coastal streams and wetland shall be maintained, where feasible, by minimizing adverse effects of waste water discharges and entrainment, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian streams, and minimizing alteration of natural streams;

- Development shall be designed to conserve water to the greatest practical extent to minimize the amounts of runoff and sanitary waste which need to be controlled to protect coastal wetlands. Drainage systems shall be designed to accommodate runoff from at least a 10-year storm. Runoff from all impervious surfaces and from all areas subject to vehicular traffic shall be collected and disposed of in a way which does not result in soil erosion or degradation of water quality;

- Environmentally sensitive habitat areas must be kept in a natural state and protected from the incursion of humans, domestic animals and livestock, from erosion, sedimentation and contaminated runoff, and from loud noise or vehicular traffic;

<u>Permitted Uses and Development Standards in Environmentally Sensitive Habitat Areas:</u>

Peat harvesting is permitted in environmentally sensitive habitat areas and grazing of a presently grazed area may be continued but not expanded. Managed observation areas may be permitted subject to an approved land and management program that preserves sensitive habitat values and minimizes human disturbance. Land in environmentally sensitive areas is excluded from calculation of lot size for number of units and allowable impervious surface area. Minimum lot size for residential use is 5 acres per housing unit. Minimum lot size for industrial use is 15 acres. The maximum impervious surface area is 10% of lot area. Minimum setback for all development or agricultural activity from riparian habitat is 50 feet; from wetland or transitional zone, 100 feet. Where development is adjacent to an environmentally sensitive habitat area appropriate tall trees shall be planted to provide a dense visual screen, impede human access, and enhance bird roosting and nesting. Native riparian species are appropriate adjacent to running water, in other areas eucalyptus or native upland species are appropriate. The maximum slope of the developed portion of a lot before grading is 15 feet in any 100 foot interval. Approved erosion control measures must be used during construction and not excavation or grading is permitted from October to March. Before approval of any development can take place in Area C (see LCP map) a field search for the endangered Santa Cruz Tarweed shall be conducted by a qualified botanist on the lot in question during the time of year in which the plant is expected to be in bloom.

3. City of Watsonville Grading and Erosion Control Ordinance

The City of Watsonville has two erosion control guidelines: one for October 15 thru April 15 and the other for April 16 thru October 14. Erosion control during the winter requires that all cut and fill slopes bare of vegetation to be planted with erosion control material. The erosion control material to be planted is a grass/legume mixture. To establish an effective grass/legume cover the ordinance recommends the following steps:

- Prepare a seedbed
- Use good quality seed in the right mixture
- Plant at the right time of year with proper technique
- Fertilize property
- Apply a suitable mulch

The guidelines specify that the necessary erosion control practices, such as berms, diversions, and catch basins be installed prior to seeding so that seeding areas are not disturbed by construction activities. In the winter, the seed mixture is to be applied along with straw mulch, sheepsfooted, and netting pinned down.

The summer erosion control measure specifies that all cut and fill slopes bare of vegetation are to be planted with a mixture of cellulose, fiber, seed, fertilizer and water (hydromulch). If, after September 1, the summer erosion controls measures have not taken root, then the winter erosion control measures are required.

4. City of Watsonville Parks and Open Space Master Plan (1991 Draft)

The purpose of the Master Plan is to provide an opportunity for public input into the parks and recreation planning process, to create an open space plan that meets the needs for active and passive recreation along with environmental and scenic preservation, to develop a program for parkland acquisition and development, and to review current recreation programs to determine if they meet the needs of the community.

The Master Plan identifies the sloughs that run through the City, as well as the creeks and river along its edge, as contributing to the City's visual character. The sloughs are recognized as a valuable and unique natural resource providing for numerous indigenous plants and animals as well as migratory birds. The plan notes that Watsonville's wetlands also provide important flood control function and create a visual fabric within the city. The plan recognizes the City's current holdings that border on wetlands, which potentially provide the opportunity for limited wetland access and educational facilities such as kiosks, interpretive signage and observation decks.

One of the objectives of the Master Plan is to facilitate protection of environmental open spaces. The Plan states that most of Watsonville's sloughs, creeks and the Pajaro River are already in public ownership; therefore, protection and enhancement will require minimal acquisition. Protection of environmental open spaces is considered more of a management and policy issue. The policies proposed are as follows:

- An environmental resources ordinance should be developed by the City to review and revise current requirements regarding development setbacks, defining sensitive habitats and ensuring adequate safeguards for both public and private developments adjacent to wetlands. In addition, such an ordinance could establish guidelines for habitat restoration and enhancement;

- Adoption of the proposed Parks and Open Space Classification System would give responsibility to the Recreation and Parks Department in coordination with the Department of Fish and Game, for long range management of the sloughs. This could include environmental education programs, enforcing no-dumping ordinances, and budgeting for environmental resource enhancement;

The design policy for parks adjacent to sloughs, rivers, or creeks is to provide facilities for environmental education and appreciation, such as boardwalks, overlooks, kiosks and interpretive signs. Elements of an environmental education program should include development of trails, interpretive signs and overlooks at public parks that are adjacent to sensitive environments, encouragement of private environmental organizations to sponsor wetlands enhancement programs, and to provide docents for wetlands tours and coordination with the School District to use specified areas as an outdoor learning laboratory.

The policy suggesting an Environmental Resources Ordinance has not been followed. Charles Eadie of the Watsonville Planning Department stated that an ordinance is not really necessary because policies are now in place that do what an ordinance would do and the Department of Fish and Game reviews each proposed development involving an environmental resource.

C. Comparison of Watsonville's General Plan Policies to Santa Cruz County Planning Objectives - Prepared by the Santa Cruz County Planning Department, September, 1994

Summary of Information Regarding Wetlands and Other Environmentally Sensitive Habitats

The Watsonville General Plan primarily designates habitat areas for open space and environmental management with the exception of a large segment of Watsonville Slough which is designated in the General Plan for commercial and industrial development. This document states that the City is currently participating with the County in an AMBAG study of "...the biotic resources of the sloughs..", and that the City General Plan suggests that the City will consider implementation of the AMBAG study's recommendations. The primary habitat protection policy of the Watsonville General Plan, however, is that habitat protection areas and impact mitigation be identified through the development and environmental review process. The City General Plan contains no habitat protection standards, and supports but does not require habitat restoration efforts. Specific plan requirements for the annexation area around Watsonville Slough will include restoration of the wetland/slough ecosystem from its current degraded status. The General Plan policies specifically allow for "habitat mitigation banking."

Recommended actions in the report include the following:

- Continue County support and participation in the AMBAG study of the Watsonville Slough system and in the Corp of Engineers' study of flood protection for the Pajaro River, and seek augmentation or expansion of the studies to develop a comprehensive resource management plan for the Watsonville Slough system consistent with County General Plan programs;

- Monitor the CEQA review of area Specific Plans and major development projects in the city to ensure that adequate habitat mitigation is incorporated into all projects;

- Seek strong habitat protection as a condition of LAFCO approval of all proposed annexations, and require guarantees of habitat protection prior to agreement to any property tax exchange affecting the property;

- Review and comment on habitat protection issues involved in any Local Coastal Programs submitted for Coastal Commission certification;

II. STATE REGULATIONS REGARDING POLLUTED RUNOFF AND WETLAND HABITAT

A. California Porter-Cologne Water Quality Act

The Porter-Cologne Water Quality Act is the principal state law governing non-point source water quality regulation in California. Porter-Cologne limits how the Regional Water Quality Control Boards can require use of stormwater management practices; however, the Regional Water Boards may set discharge limitations such that the only practical way to comply is to use management practices.

B. California Environmental Quality Act (CEQA)

This act was patterned after the National Environmental Policy Act (NEPA) and set forth the state's basic charter for the protection of the environment. The act requires that projects which may have a significant effect on the environment and which involve discretionary governmental action be subject to an environmental review process.

C. State Water Resources Control Board (SWRCB) and California Regional Water Quality Control Board

The SWRCB has responsibility for the State's water quality and water rights programs. State policies set forth by the SWRCB are administered by the Regional Water Quality Control Boards (RWQCB). Water quality standards for individual projects are established by the RWQCB as part of the National Pollutant Discharge Elimination System (NPDES) permit procedure under the Federal Clean Water Act (see below). The NPDES program applies to all discharges to surface waters including wetlands. The SWRCB has elected to issue a statewide general permit for all stormwater discharges requiring an NPDES permit. Municipalities on the other hand must obtain an individual or regional NPDES stormwater permit for their entire storm drainage system.

The State Porter-Cologne Act is the principal vehicle for controlling stormwater pollutants. The Act requires that each RWQCB adopt Basin Plans for drainage basins within California. The plans designate water quality objectives to ensure the reasonable protection of beneficial uses of the region's water resources as required by the Porter-Cologne Act.

D. California Department of Fish and Game

The Department of Fish and Game (DFG) has specific regulatory responsibilities as well as managing programs for the preservation and protection of fish and wildlife habitat. The DFG administers provision of the state Endangered Species Act. The DFG policy on wetlands is drawn from the Keene-Nejedly California Wetlands Preservation Act of 1976 which states the "need for an affirmative and sustained public policy and program directed at [wetlands] preservation, restoration, and enhancement, in order that such wetlands shall continue in perpetuity." DFG regulatory activities includes the following:

- Reviewing projects with the potential to divert/obstruct natural flows or change the bed or channel of DFG-designated rivers, streams, or lakes through Fish and Game Code Section 1601-1603.

- Review and comment on all forms of development-related processes (e.g., State Lands permits, EIRs/EISs, Corps of Engineers Section 10 and 404 permits). A state land agency must consult with DFG to determine if its project is "likely to jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of habitat essential to continued existence of the species." (Calif. Fish and Game Code 2090).

- Management of wildlife areas and ecological reserves.

- Enforcing against any material being put into the State's waters that is deliterious to fish or wildlife through Fish and Game Code Section 5650.

E. California Coastal Commission

The Coastal Act requires that all development within the Coastal Zone receive coastal development permits. Portions of the Watsonville Slough watershed fall within the Coastal Zone. Both Santa Cruz County and the City of Watsonville have certified local coastal programs which give them the authority to issue coastal development permits (see Local policies portion of this appendix). The certified local coastal programs are based on Coastal Act policies, including 30233 and 30240 regarding wetlands and environmentally sensitive habitat area protection.

The California Coastal Commission (along with the State Water Resources Control Board) is charged with developing the state's coastal non-point pollution control program described under the Coastal Zone Management Act section of this appendix. The following table describes the law's requirements and the state's response. The table is taken from the Coastal Commission's "Procedural Guidance Manual: Addressing Polluted Runoff in the California Coastal Zone," May 1, 1995, which is a valuable reference document.

Table 2-1. Coastal Nonpoint Pollution Control Program Requirements [16 U.S.C. §1455b(b)(1)-(7)]

1. <u>**Identify land uses**</u> that individually or cumulatively may cause or contribute significantly to degradation of coastal waters. 2. <u>**Implement and revise additional management measures**</u> applicable to the land uses and areas identified above to attain and maintain water quality standards and protect designated beneficial uses.	The State's requirements under CZARA Section 6217 include: • Identify categories and subcategories of land uses that impact coastal waters for which management measures will be implemented; • Describe the 6217(g) guidance management measures and state-developed additional management measures to be implemented; • Describe the procedures the State will use to ensure implementation of the management measures, including operation and maintenance practices, inspection and certification procedures, and monitoring; and • Identify land uses and critical coastal areas that will require additional management measures. In 1994, the SWRCB initiated a review of polluted runoff management using Technical Advisory Committees (TACs). The TACs reviewed the following types of nonpoint sources and land uses: (1) Irrigated Agriculture; (2) Nutrient Application; (3) Pesticide Application; (4) Confined Animal Facilities; (5) Grazing; (6) Abandoned Mines; (7) Urban Runoff; (8) Hydromodification and Wetlands; (9) Onsite Sewage Disposal Systems; and (10) Boating and Marinas. The SWRCB and Coastal Commission are now developing a statewide program to implement polluted runoff management measures, including identifying additional management measures, designating a lead state agency for each runoff source category/subcategory, describing enforceable policies/mechanisms to implement the measures, and describing how the lead agency and associated state/local agencies will implement the program.
3. <u>**Identify "Critical Coastal Areas"**</u> encompassing land uses as identified under CZARA §6217(b)(1) [16 U.S.C. §1455b (b) (1)].	The SWRCB and Coastal Commission are developing Critical Coastal Areas by identifying threatened and impaired waterbodies and defining geographic areas adjacent to threatened or impaired coastal waters within which any new land uses or substantial expansion of existing land uses shall be subject to additional management measures (i.e., measures in addition to those promulgated in the U.S. EPA (1993a) *"g" Guidance*). In California, the agencies have identified approximately 30 hydrologic subareas directly adjacent to threatened or impaired waterbodies.
4. <u>**Provide assistance**</u> to local governments to implement additional polluted runoff management measures.	Examples of the types of assistance that states can provide local governments include: (1) help in developing ordinances and regulations to prevent or control polluted runoff; (2) technical guidance; (3) modeling to predict and assess the effectiveness of management measures when used; (4) training; (5) financial incentives; (6) demonstration projects; and (7) other innovations to protect coastal water quality and designated beneficial uses [16 U.S.C. §1455b(b)(4)]. NOAA and the U.S. EPA (1993a) expect states to identify those portions of the coastal nonpoint program to be implemented by local governments and to develop programs to provide assistance to local governments.

Table 2-1. Coastal Nonpoint Pollution Control Program Requirements [16 U.S.C. §1455b(b)(1)-(7)]

4. **Provide assistance** to local governments to implement additional polluted runoff management measures. *(continued)*	To meet these requirements, the Coastal Commission can build upon existing local government partnerships. For example, the Commission staff can provide technical assistance to local governments in implementing the U.S. EPA-promulgated management measures during LCP and CDP review and approval and the LCP post-certification processes.
5. **Provide opportunities for public participation** in CNPCP development and implementation via public notices, public comment, public hearings, technical and financial assistance, and public education.	To date, SWRCB TACs composed of members of affected user groups and people with water quality expertise have reviewed the polluted runoff strategies currently applied in California, compared them to the U.S. EPA-promulgated management measures, and identified management and regulatory gaps. Additional public participation will occur through workshops and hearings held by the Coastal Commission, BCDC, and the SWRCB prior to adopting changes to the CCMP and the State's Nonpoint Source Management Program. These workshops will be targeted for various audiences including federal and State agency staffs, local officials and agency staffs, affected constituency groups, public interest groups and the general public.
6. **Improve coordination** among state, regional, and local agencies (those responsible for land use permitting and enforcement, water quality, habitat protection, and public health and safety) through the development of institutional/ administrative mechanisms.	The Commission currently uses a number of approaches to coordinate its regulatory programs with other agencies. However, because of the new program requirements under CZARA Section 6217, a heightened level of coordination will be required to successfully implement the state CNPCP. Mechanisms that can potentially improve agency coordination include: (1) watershed planning; (2) Memoranda of Agreement (MOAs) or Memoranda of Understanding (MOUs) describing specific agency roles and points of coordination; (3) joint permitting processes; (4) formal interagency comments before other agency permitting processes are initiated; (5) temporary assignment of staff to other agencies [e.g., Intergovernmental Personnel Agreements (IPAs)]; (6) cross-training of staff in other agency programs; (7) interagency task forces (e.g., those associated with National Estuary Programs, National Marine Sanctuaries or National Estuarine Research Reserves) and advisory committees; (8) regularly scheduled interagency staff meetings; and (9) state statutes/regulations describing expectations for interagency cooperation and coordination (U.S. EPA and NOAA, 1993a).
7. **Evaluate the need to adjust the state coastal zone boundary** inland to manage land and water uses more effectively.	In March 1993, NOAA recommended that California adopt a management area that extends significantly inland of the coastal zone boundary in order to have better regulatory control over land and water uses that, individually or cumulatively, have a significant impact on coastal waters. In developing this recommendation, NOAA generally used coastal watersheds as an appropriate boundary for a polluted runoff management area. To preclude the need for a boundary change or to develop separate programs for the coastal zone and coastal watersheds outside the coastal zone, California will ensure that revisions to its existing statewide NPS program will fulfill the requirements of CZARA.

IV. FEDERAL REGULATIONS REGARDING POLLUTED RUNOFF AND WETLAND HABITAT

A. Clean Water Act

The Federal Water Pollution Control Act of 1972, commonly referred to as the Clean Water Act (CWA), was enacted to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Clean Water Act established the National Pollutant Discharge Elimination System (NPDES) permit program. All point source dischargers (i.e. those with sewage or industrial wastewater outfalls) are required to obtain NPDES permits. The 1987 Amendments to the CWA set forth new provisions to address nonpoint source water pollution by requiring permits for the discharge of stormwater from both municipal and industrial stormwater runoff dischargers.

1. National Pollutant Discharge Elimination System (NPDES) Stormwater Permit Program

Currently, larger cities (those of over 100,000 in population) and certain types of industrial facilities are required to clean up their stormwater runoff by complying with an NPDES stormwater permit. In California, construction sites of where over five acres are disturbed are also required to get an NPDES Stormwater permit. Significant sources of polluted runoff that are not presently covered by the NPDES federal stormwater regulations include municipalities with populations under 100,000, construction sites less than 5 acres in size, and commercial and small industrial sites not specifically listed in statute (such as automobile service stations).

a. Municipal Stormwater Permits

The municipal NPDES stormwater permit program is a two-phased program enacted by Congress in 1987 under Section 402(p) of the CWA. Participants in the NPDES Municipal Stormwater Permit program are responsible for development and implementation of stormwater management plans (SWMP) to prevent the pollution of stormwater within the permitted areas. The SWMP must detail how the permittee will eliminate non-storm water discharges, and apply best management practices, to the maximum extent practicable, to prevent or minimize stormwater pollution.

b. Industrial Stormwater Permits

List types of industrial activities regulated.
Describe general permit requirements
List some or all of the permit holders in the slough system watershed.

c. Construction Activity Stormwater Permits

Describe general permit requirements

2. CWA Section 404 Wetland Filling/Dredging Permit Program

Section 404 of the Clean Water Act regulates the discharge of dredged and fill material into water of the United States, and establishes a permit program to ensure that such discharges comply with environmental requirements. At the federal level, the Section 404 program is administered by the U.S. Army Corps of Engineers (the Corps) and the Environmental Protection Agency (EPA). The EPA has veto authority over the issuance by the Corps of the 404 permit; however, it has seldom used this power (Steiner, Peiart and Cook 1991). The U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) have important advisory roles. The Corps has the primary responsibility for the permit program and is authorized, after notice and opportunity for a public hearing, to issue permits for the discharge of dredged or fill material. The EPA is responsible for development of the environmental guidelines by which permit applications must be evaluated; review of proposed permits; prohibition of discharges with unacceptable adverse impacts; approval and oversight of State assumption of the program; establishment of the jurisdictional scope of waters of the U.S.; and interpretation of Section 404 exemptions. Enforcement authority is shared between EPA and the Corps.

Section 404 program regulations define wetlands as "...those areas that are inundated or saturated with surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." To apply this definition in the field, government scientists use indicators of vegetation, soils, and hydrology to identify wetlands and to establish their boundaries.

The activities regulated by Section 404 includes activities such as port development, channel construction and maintenance, filling wetlands to create development sites, transportation improvements, and water resource projects. Some activities that may adversely affect wetlands, such as drainage or ground water pumping, are often conducted without discharging dredged or fill material into waters of the United States and, therefore, are not regulated under Section 404.

The federal Clean Water Act includes activities subject to specific exemptions from permitting requirements including:

- Normal farming, silviculture, and ranching practices;
- Maintenance and emergency reconstruction of recently damaged parts of currently serviceable structures such as dikes, dams, levees, groins, rip rap, breakwaters, causeways, bridge abutments or approaches, and transportation structures;
- Construction or maintenance of farm or stock ponds or irrigation ditches, or the maintenance of drainage ditches;
- Construction of temporary sedimentation basins;
- Construction or maintenance of farm or forest roads or temporary roads for moving mining equipment if best management practices are followed;

B. Coastal Zone Management Act (1972) and Amendments

The Coastal Zone Management Act is designed to help coastal states develop their own plans to manage and protect coastal zone resources by providing financial and technical assistance during the planning and administration of programs that meet minimum federal standards. The Reauthorization Amendments of 1990 made the following major changes to the Act of 1972:

- All federal agency activities are subject to consistency with state coastal zone management plans if they affect natural resources, land-uses, or water uses in the coastal zone
- Enhancement grants are provided for coastal states with approved coastal zone management programs to continually improve their programs in several areas including coastal wetlands management and protection
- A Coastal Nonpoint Pollution Control Program was established requiring each coastal state to develop a management program to address coastal nonpoint pollution.

1. Coastal Nonpoint Pollution Control Program

Section 6217(g) of the Coastal Zone Act Reauthorization Amendments (CZARA) requires California to implement a Coastal Nonpoint Pollution Control Programs (CNPCP). California's CNPCP includes "management measures" to control nonpoint source pollution in coastal waters. The management measures are in conformity with the management measures listed in a guidance document called Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, or simply *(g) Guidance*, published by the United States Environmental Protection Agency (EPA). The (g) Guidance includes measures to address certain urban runoff; however, all storm water dischargers covered by Phase I of the CWA NPDES stormwater permit program (municipal separate storm sewers serving populations greater that 100,000 people and certain industrial activities) are excluded from coverage under the CZARA 6217. Under Phase II, EPA is expected to issue regulations that apply to municipalities of under 100,000 population, although at this time it is not certain when Phase II will commence.

Dischargers that may be ultimately covered by Phase II of the storm water NPDES permit program are covered by the management measures guidance and must be addressed by the coastal nonpoint pollution control program. Activities that are covered by the CNPCP include construction activities on sites less than 5 acres, discharges from retail, commercial or wholesale activities, service stations and large parking lots. Table 1 shows a comparison of pollution sources covered by CZARA Management Measures and NPDES Storm Water Permits.

Table 1. Comparison of Urban Pollution Sources Covered by CZARA Management Measures and NPDES Stormwater Permits

Pollution Source	Covered by CZARA Management Measures	Covered by NPDES Permitting
New Development (populations ≥ 100,000)	No	Yes
New Development (populations < 100,000)	Yes	No although the RWQCB may permit a system serving a population < 100,000 on a case-by-case basis
Construction site < 5 acres	Yes	No
Construction site ≥ 5 acres	No	Yes
Retail, commercial or wholesale activities	Yes	No
Service Stations	Yes	No
Industrial activities	No	Yes
Hazardous waste treatment, storage, and disposal facilities	No	Yes
Household hazardous waste	Yes	No
Landfills that receive industrial waste	No	Yes
Recycling facilities	No	Yes
Transportation facilities with vehicle maintenance operations	No	Yes
Roads, highways, and bridge operations, and maintenance	Yes	No
Large parking lots	Yes	No
On-site disposal systems	Yes	No
Residential property including lawns and landscaped areas	Yes	No
Recreational areas	Yes	No
Greenhouses and nurseries	Yes	No
Illicit connections and discharges	Partial, when not a part of NPDES program or combined sewer overflow	Yes

Source: Urban Runoff Technical Advisory Committee Report and Recommendations, November, 1994.

C. National Environmental Policy Act (NEPA)

The National Environmental Policy Act of 1969 requires consideration of the adverse impacts on environmental resources caused by any federal action, including federally funded or permitted projects. It also requires examination of alternative to minimize those impacts. Environmental investigations carried out in accordance with NEPA are documented in an environmental assessment or an environmental impact statement.

D. Rivers and Harbors Act (1899) Section 10

The Rivers and Harbors Act of 1899 regulated all construction in or modification of traditionally navigable waters. Section 10 prohibits the unauthorized obstruction or alteration of any navigable waters of the United States. It is similar to Section 404 of the Clean Water Act in that it requires permits issued by the Corps for any dredging, filling, or obstruction of navigable waters. When a project requires applications for permits under both the Clean Water and River and Harbors Acts, the Corps often conducts the two permit reviews concurrently. It differs from Section 404 in that the activities it covers are much broader that those regulated under Section 404 and its jurisdiction extends only to the high water line. Within areas covered, the Rivers and Harbors Act offers greater regulatory authority but it does not apply to all areas regulated under Section 404.

E. Food Security Act (1985)

The "swampbuster" provision of the Food Security Act of 1985 discourages the conversion of wetlands to farmland by making any person who produces crops on wetlands converted after December 23, 1985, ineligible for most federal farm benefits. A second provision of the Food Security Act is the Conservation Reserve Program (CRP). This program is designed to remove highly erodible croplands from production. While CRP was not initially designed for wetlands protection, wetlands have been added to the program.

F. Department of Agriculture ASCS Water Bank Program

Since 1972, the U.S. Department of Agriculture's Agricultural Stabilization and Conservation Service (ASCS) has offered landowners payments in exchange for agreements to maintain wetlands on their property. Participating landowners sign 10-year easement contracts to keep wetlands and other wildlife habitats in their natural state.

G. Emergency Wetlands Resources Act (1986)

The 1986 Emergency Wetlands Resources Act expands and enhances the sources of funds for wetlands acquisition. The law also directs the Secretary of the Interior to develop, in consultation with EPA and other federal and state agencies, a National Wetlands Priority conservation Plan that identifies the type of wetlands and wetland interests to be given priority for federal and state acquisition.

The Act directed the U.S. Fish and Wildlife Service to complete mapping project of wetland resources, called the National Wetlands Inventory (NWI), of the conterminous United States by 1998 and Alaska as soon as practical thereafter. The law also mandated that status and trend reports be completed at ten year intervals.

H. Executive Orders 11988 and 11990

These Executive Orders were signed by President Carter in 1977 affecting federal agency actions with respect to wetlands. Executive Order 11988 requires written justification for projects proposed to be located in a floodplain and Executive Order 11990 directs federal agencies to take active measures to protect wetlands and requires that they avoid activities that have adverse impacts to wetlands.

I. U.S. Fish and Wildlife Service Programs

The Fish and Wildlife Service administers a number of wetland acquisition programs. The Migratory Bird Hunting and Conservation Stamp Act of 1934 requires waterfowl hunters to buy "duck stamps" to acquire migratory waterfowl habitat and the Small Wetlands Acquisition Program offers a landowner the opportunity to sell a wetland or enter into an easement agreement. The Fish and Wildlife Service is also involved in the Land and Water Conservation Fund (LWCF) to allocate money to the states for acquisition and development projects and the North American Waterfowl Management Plan formulated in 1986 as a general strategy for cooperation among Canada, the United States, and Mexico in the maintenance and enhancement of waterfowl population and habitats.

The Fish and Wildlife Coordination Act requires the Corps to consult the USFWS and the National Marine Fisheries Service (NMFS) during preparation of an environmental review prior to issuance of a permit. The USFWS Mitigation Policy provides internal guidance for establishing appropriate compensation goals for projects impacting waters of the United States. (Questa Engineering's Petaluma Marsh Enhancement Plan).

J. Endangered Species Act

Some wetlands are offered protection under the Endangered Species Act as habitats for threatened and endangered species. Among its provisions, Section 7 of the Act requires federal agencies to ensure that any actions they authorize, fund, or carry out will not jeopardize the continued existence of any listed species, or result in the destruction or adverse modification of its designated critical habitat.

K. EPA's Coastal Protection Activities

The EPA's Office of Wetlands, Oceans, and Watersheds (OWOW) Oceans and Coastal Protection Division (OCPD) is responsible for addressing growing coastal and ocean problems through pollution prevention efforts, geographic-based approaches, and enforcement. OWOW shares responsibility with numerous other EPA offices, federal agencies, and states for implementing the basic requirements of the Clean Water Act. Point source discharges to marine and estuarine waters are regulated through National Pollutant Discharge Elimination System (NPDES) permits that set limits on effluents and define monitoring and reporting requirements.

The passage of the Water Quality Act of 1987 authorizes EPA to convene management conferences to develop comprehensive conservation and management plans for estuaries of national significance that are threatened by pollution, development, or overuse. The EPA, in managing the National Estuary Program, is directed to identify nationally significant estuaries threatened by pollution, development, or overuse, and to promote the preparation of comprehensive management plans to ensure their ecological integrity.

APPENDIX C

WATER BUDGET CALCULATIONS

Monthly Water Budget for Harkins Slough - September

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Aug)	FROM PRIOR 2 MONTHS (50% of Jul)	FROM PRIOR 3 MONTHS (25% of Jun)	TOTAL
AG	89	99	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	-2.56	0.00	-2.56
URBAN	87	142	33	0.3	1.2	0.3	0	0.0	49	0.0	0.0	0	-3.67	0.00	-3.67
AG	85	354	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	-9.15	0.00	-9.15
URBAN	83	220	22	0.3	1.2	0.3	0	0.0	0	0.0	0.0	0	-5.68	0.00	-5.68
OPEN	80	1586	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	-40.97	0.00	-40.97
AG	78	815	0	0.3	0.0	0.3	0	0.0	574	0.0	0.0	0	-16.35	0.00	-16.35
OPEN	74	2316	0	0.3	0.0	0.3	0	0.0	1169	0.0	0.0	0	-59.83	0.00	-59.83
TOTAL		**5532**			**2.4**			**0.0**	**1792.0**	**0.0**	**0.0**	**0.0**	**-138.21**	**0.00**	**-138.21**

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - September

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Aug)	FROM PRIOR 2 MONTHS (50% of Jul)	FROM PRIOR 3 MONTHS (25% of Jun)	TOTAL
OPEN	82	319	0	0.3	0.0	0.3	0	0.0	69	0.0	0.0	0	-8.24	0.00	-8.24
AG	78	350	0	0.3	0.0	0.3	0	0.0	117	0.0	0.0	0	-9.04	0.00	-9.04
URBAN	75	69	15	0.3	0.3	0.3	0	0.0	1	0.0	0.0	0	-1.78	0.00	-1.78
OPEN	74	776	0	0.3	0.0	0.3	0	0.0	664	0.0	0.0	0	-20.05	0.00	-20.05
TOTAL		**1514**			**0.3**			**0.0**	**851.0**	**0.0**	**0.0**				**-39.11**

Monthly Water Budget for Watsonville Slough - September

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Aug)	FROM PRIOR 2 MONTHS (50% of Jul)	FROM PRIOR 3 MONTHS (25% of Jun)	TOTAL
URBAN	95	1019	68	0.3	17.3	0.3	0	0.0	0	0.0	0.0	0	-26.32	0.00	-26.32
URBAN	92	205	55	0.3	2.8	0.3	0	0.0	0	0.0	0.0	0	-5.30	0.00	-5.30
AG	89	200	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	-5.17	0.00	-5.17
URBAN	87	263	37	0.3	2.4	0.3	0	0.0	0	0.0	0.0	0	-6.79	0.00	-6.79
AG	85	733	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	-18.94	0.00	-18.94
URBAN	83	321	28	0.3	2.2	0.3	0	0.0	10	0.0	0.0	0	-1.47	0.00	-1.47
OPEN	82	927	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	-1.55	0.00	-1.55
AG	78	79	0	0.3	0.0	0.3	0	0.0	124	0.0	0.0	0	-99.82	0.00	-99.82
OPEN	74	57	0	0.3	0.0	0.3	0	0.0	0	0.0	0.0	0	0.00	0.00	0.00
OPEN	61	60	0	0.3	0.0	0.3	0	0.0	30.8	0.0	0.0	0	0.00	0.00	0.00
TOTAL		**3864**			**24.8**			**0.0**	**164.8**	**0.0**	**0.0**				**-165.36**

Monthly Water Budget for Harkins Slough - October

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Sept)	FROM PRIOR 2 MONTHS (50% of Aug)	FROM PRIOR 3 MONTHS (25% of Jul)	TOTAL
AG	89	99	0	1.1	0.0	1.1	0	0.0	0	0.0	0.0	0.0	0	-1.27875	-1.3
URBAN	87	142	33	1.1	4.3	1.1	-0.363	-4.3	49	0.0	-4.3	0.0	0	-1.83416666667	-1.8
AG	85	354	0	1.1	0.0	1.1	0	0.0	0	0.0	0.0	0.0	0	-4.5725	-4.6
URBAN	83	220	22	1.1	4.4	1.1	-0.242	-4.4	0	0.0	-4.4	0.0	0	-2.84166666667	-2.8
OPEN	80	1586	0	1.1	0.0	1.1	0	0.0	0	0.0	0.0	0.0	0	-20.4858333333	-20.5
AG	78	633	0	1.1	0.0	1.1	0	0.0	574	0.0	0.0	0.0	0	-8.17625	-8.2
OPEN	74	2316	0	1.1	0.0	1.1	0	0.0	1169	0.0	0.0	0.0	0	-29.915	-29.9
TOTAL		**5350**			**8.7**			**-8.7**	**1792.0**	**0.0**	**-8.7**	**0.0**	**0.0**	**-69.1**	**-69.1**

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - October

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Sept)	FROM PRIOR 2 MONTHS (50% of Aug)	FROM PRIOR 3 MONTHS (25% of Jul)	TOTAL
OPEN	82	319	0	1.1	0.0	1.1	0	0.0	69	0.0	0.0	0.0	0	-4.12041666667	-4.1
AG	78	350	0	1.1	0.0	1.1	0	0.0	117	0.0	0.0	0.0	0	-4.52083333333	-4.5
URBAN	75	69	15	1.1	0.9	1.1	0	0.0	1	0.0	0.0	0.0	0	-0.89125	-0.9
OPEN	74	776	0	1.1	0.0	1.1	0	0.0	664	0.0	0.0	0.0	0	-10.0233333333	-10.0
TOTAL		**1514**			**0.9**			**0.0**	**851.0**	**0.0**	**0.0**				**-19.6**

Monthly Water Budget for Watsonville Slough - October

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Sept)	FROM PRIOR 2 MONTHS (50% of Aug)	FROM PRIOR 3 MONTHS (25% of Jul)	TOTAL
URBAN	95	1019	68	1.1	63.5	1.1	0	0.0	0	0.0	0.0	0.0	0	-13.1620833333	-13.2
URBAN	92	205	55	1.1	10.3	1.1	0	0.0	0	0.0	0.0	0.0	0	-2.64791666667	-2.6
AG	89	200	0	1.1	0.0	1.1	0	0.0	0	0.0	0.0	0.0	0	-2.58333333333	-2.6
URBAN	87	263	37	1.1	8.9	1.1	0	0.0	0	0.0	0.0	0.0	0	-3.39708333333	-3.4
AG	85	733	0	1.1	0.0	1.1	0	0.0	0	0.0	0.0	0.0	0	-9.46791666667	-9.5
URBAN	83	321	28	1.1	8.2	1.1	0	0.0	10	0.0	0.0	0.0	0	-0.73625	-0.7
OPEN	82	927	0	1.1	0.0	1.1	0	0.0	0	0.0	0.0	0.0	0	-0.775	-0.8
AG	78	79	0	1.1	0.0	1.1	0	0.0	124	0.0	0.0	0.0	0	-49.91	-49.9
OPEN	74	57	0	1.1	0.0	1.1	0	0.0	10	0.0	0.0	0.0	0	-0.73625	-0.7
OPEN	61	60	0	1.1	0.0	1.1	0	0.0	30.8	0.0	0.0	0.0	0	-0.775	-0.8
TOTAL		**3864**			**91.0**			**0.0**	**174.8**	**0.0**	**0.0**				**-84.2**

Monthly Water Budget for Harkins Slough - November

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Oct)	FROM PRIOR 2 MONTHS (50% of Sept)	FROM PRIOR 3 MONTHS (25% of Aug)	TOTAL
AG	89	99	15	3.25	4.0	2.3	0.4625	3.8	0	0.0	3.8	0.0	0.0	0	0.0
URBAN	87	142	33	3.25	12.7	2.3	-0.1225	-1.4	49	0.0	-1.4	-1.1	0.0	0	-1.1
AG	85	354	15	3.25	14.4	2.3	0.4625	13.6	0	0.0	13.6	0.0	0.0	0	0.0
URBAN	83	220	22	3.25	13.1	2.3	0.235	4.3	0	0.0	4.3	-1.1	0.0	0	-1.1
OPEN	80	1586	0	3.25	0.0	2.3	0.95	125.6	0	0.0	125.6	0.0	0.0	0	0.0
AG	78	633	0	3.25	0.0	2.3	0.95	50.1	574	45.4	4.7	0.0	0.0	0	0.0
OPEN	74	2316	0	3.25	0.0	2.3	0.95	183.4	1169	92.5	90.8	0.0	0.0	0	0.0
TOTAL		5350			44.2			379.3	1792.0	138.0	241.4	-2.2	0.0	0.0	-2.2

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - November

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Oct)	FROM PRIOR 2 MONTHS (50% of Sept)	FROM PRIOR 3 MONTHS (25% of Aug)	TOTAL
OPEN	82	319	15	3.25	13.0	2.3	0.4625	12.3	69	2.7	9.6	0.0	0.0	0	0.0
AG	78	350	33	3.25	31.3	2.3	-0.1225	-3.6	117	0.0	-3.6	0.0	0.0	0	0.0
URBAN	75	69	27	3.25	5.0	2.3	0.0725	0.4	1	0.0	0.4	0.0	0.0	0	0.0
OPEN	74	776	0	3.25	0.0	2.3	0.95	61.4	664	52.6	8.9	0.0	0.0	0	0.0
TOTAL		1514			49.3			70.6	851.0	55.2	15.3				0.0

Monthly Water Budget for Watsonville Slough - November

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Oct)	FROM PRIOR 2 MONTHS (50% of Sept)	FROM PRIOR 3 MONTHS (25% of Aug)	TOTAL
URBAN	95	1019	68	3.25	187.7	2.3	0	0.0	0	0.0	0.0	0.0	0.0	0	0.0
URBAN	92	205	55	3.25	30.5	2.3	0	0.0	0	0	0.0	0.0	0.0	0	0.0
AG	89	200	15	3.25	8.1	2.3	0.4625	7.7	0	0	7.7	0.0	0.0	0	0.0
URBAN	87	263	37	3.25	26.4	2.3	0	0.0	0	0	0.0	0.0	0.0	0	0.0
AG	85	733	15	3.25	29.8	2.3	0.4625	28.3	0	0	28.3	0.0	0.0	0	0.0
URBAN	83	321	28	3.25	24.3	2.3	0	0.0	10	0	0.0	0.0	0.0	0	0.0
OPEN	82	927	10	3.25	25.1	2.3	0.625	48.3	0	0	48.3	0.0	0.0	0	0.0
AG	78	79	15	3.25	3.2	2.3	0.4625	3.0	124	0	3.0	0.0	0.0	0	0.0
OPEN	74	57	0	3.25	0.0	2.3	0.95	4.5	0	0	4.5	0.0	0.0	0	0.0
OPEN	61	60	0	3.25	0.0	2.3	0.95	4.8	30.8	0	4.8	0.0	0.0	0	0.0
TOTAL		3864			335.1			96.5	164.8	0.0	96.5				0.0

Monthly Water Budget for Harkins Slough - December

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Nov)	FROM PRIOR 2 MONTHS (50% of Oct)	FROM PRIOR 3 MONTHS (25% of Sept)	TOTAL
AG	89	99	46	3.25	12.3	1.6	0.155	1.3	0	0.0	1.3	1.0	0.0	0.0	1.0
URBAN	87	142	40	3.25	15.4	1.6	0.35	4.1	49	1.4	2.7	-0.4	-2.1	0.0	-2.5
AG	85	354	34	3.25	32.6	1.6	0.545	16.1	0	0.0	16.1	3.4	0.0	0.0	3.4
URBAN	83	220	28	3.25	16.7	1.6	0.74	13.6	0	0.0	13.6	1.1	-2.2	0.0	-1.1
OPEN	80	1586	22	3.25	94.5	1.6	0.935	123.6	0	0.0	123.6	31.4	0.0	0.0	31.4
AG	78	633	22	3.25	37.7	1.6	0.935	49.3	574	44.7	4.6	1.2	0.0	0.0	1.2
OPEN	74	2316	12	3.25	75.3	1.6	1.26	243.2	1169	122.7	120.4	22.7	0.0	0.0	22.7
TOTAL		5350			284.5			451.1	1792.0	168.9	282.2	60.3	-4.4	0.0	56.0

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - December

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Nov)	FROM PRIOR 2 MONTHS (50% of Oct)	FROM PRIOR 3 MONTHS (25% of Sept)	TOTAL
OPEN	82	319	20	3.25	17.3	1.6	1	26.6	69	5.7	20.8	2.4	4.8	0.0	7.2
AG	78	350	15	3.25	14.2	1.6	1.1625	33.9	117	11.3	22.6	-0.9	-1.8	0.0	-2.7
URBAN	75	69	15	3.25	2.8	1.6	1.1625	6.7	1	0.1	6.6	0.1	0.2	0.0	0.3
OPEN	74	776	10	3.25	21.0	1.6	1.325	85.7	664	73.3	12.4	2.2	4.4	0.0	6.7
TOTAL		1514			55.3			152.9	851.0	90.5	62.4				11.5

Monthly Water Budget for Watsonville Slough - December

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Nov)	FROM PRIOR 2 MONTHS (50% of Oct)	FROM PRIOR 3 MONTHS (25% of Sept)	TOTAL
URBAN	95	1019	68	3.25	187.7	1.6	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
URBAN	92	205	55	3.25	30.5	1.6	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
AG	89	200	43	3.25	23.3	1.6	0.2525	4.2	0	0.0	4.2	1.9	3.9	0.0	5.8
URBAN	87	263	37	3.25	26.4	1.6	0.4475	9.8	0	0.0	9.8	0.0	0.0	0.0	0.0
AG	85	733	34	3.25	67.5	1.6	0.545	33.3	0	0.0	33.3	7.1	14.1	0.0	21.2
URBAN	83	321	28	3.25	24.3	1.6	0.74	19.8	10	0.6	19.2	0.0	0.0	0.0	0.0
OPEN	82	927	25	3.25	62.8	1.6	0.8375	64.7	0	0.0	64.7	12.1	24.1	0.0	36.2
AG	78	79	18	3.25	3.9	1.6	1.065	7.0	124	11.0	-4.0	0.8	1.5	0.0	2.3
OPEN	74	57	9	3.25	1.4	1.6	1.3575	6.4	0	0.0	6.4	1.1	2.3	0.0	3.4
OPEN	61	60	0	3.25	0.0	1.6	1.65	8.3	30.8	4.2	4.0	1.2	2.4	0.0	3.6
TOTAL		3864			427.7			153.5	164.8	15.9	137.7				72.4

Monthly Water Budget for Harkins Slough - January

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Dec)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR 2 MONTHS (50% of Nov)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR 3 MONTHS (25% of Oct)	TOTAL
AG	89	99	49	4.5	18.2	1.8	0.495	4.1	0	0.0	4.1	0.3	1.9	0.0	2.2
URBAN	87	142	42	4.5	22.4	1.8	0.81	9.6	49	3.3	6.3	0.7	-0.7	-1.1	-1.1
AG	85	354	37	4.5	49.1	1.8	1.035	30.5	0	0.0	30.5	4.0	6.8	0.0	10.8
URBAN	83	220	29	4.5	23.9	1.8	1.395	25.6	0	0.0	25.6	3.4	2.2	-1.1	4.4
OPEN	80	1586	24	4.5	142.7	1.8	1.62	214.1	0	0.0	214.1	30.9	62.8	0.0	93.7
AG	78	633	22	4.5	52.2	1.8	1.71	90.2	574	81.8	8.4	1.1	2.3	0.0	3.5
OPEN	74	2316	12	4.5	104.2	1.8	2.16	416.9	1169	210.4	206.5	30.1	45.4	0.0	75.5
TOTAL		5350			412.8			791.0	1792.0	295.5	495.4				189.1

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - January

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Dec)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR 2 MONTHS (50% of Nov)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR 3 MONTHS (25% of Oct)	TOTAL
OPEN	82	319	24	4.5	28.7	1.8	1.62	43.1	69	9.3	33.8	5.2	4.8	0.0	10.0
AG	78	350	20	4.5	26.3	1.8	1.8	52.5	117	17.6	35.0	5.6	-1.8	0.0	3.9
URBAN	75	69	15	4.5	3.9	1.8	2.025	11.6	1	0.2	11.5	1.6	0.2	0.0	1.9
OPEN	74	776	12	4.5	34.9	1.8	2.16	139.7	664	119.5	20.2	3.1	4.4	0.0	7.5
TOTAL		1514			93.8			246.9	851.0	146.6	100.3				23.3

Monthly Water Budget for Watsonville Slough - January

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Dec)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR 2 MONTHS (50% of Nov)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR 3 MONTHS (25% of Oct)	TOTAL
URBAN	95	1019	68	4.5	259.8	1.8	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
URBAN	92	205	55	4.5	42.3	1.8	0.225	3.8	0	0.0	3.8	0.0	0.0	0.0	0.0
AG	89	200	46	4.5	34.5	1.8	0.63	10.5	0	0.0	10.5	1.1	3.9	0.0	4.9
URBAN	87	263	37	4.5	36.5	1.8	1.035	22.7	0	0.0	22.7	2.5	0.0	0.0	2.5
AG	85	733	37	4.5	101.7	1.8	1.035	63.2	0	0.0	63.2	8.3	14.1	0.0	22.4
URBAN	83	321	28	4.5	33.7	1.8	1.44	38.5	10	1.2	37.3	4.8	0.0	0.0	4.8
OPEN	82	927	24	4.5	83.4	1.8	1.62	125.1	0	0.0	125.1	16.2	24.1	0.0	40.3
AG	78	79	20	4.5	5.9	1.8	1.8	11.9	124	18.6	-6.8	-1.0	1.5	0.0	0.5
OPEN	74	57	10	4.5	2.1	1.8	2.25	10.7	0	0.0	10.7	1.6	2.3	0.0	3.9
OPEN	61	60	2	4.5	0.5	1.8	2.61	13.1	30.8	6.7	6.4	1.0	2.4	0.0	3.4
TOTAL		3864			600.5			299.5	164.8	26.5	273.0	34.4	48.3	0.0	82.7

Monthly Water Budget for Harkins Slough - Febuary

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT): FROM PRIOR MONTH (25% of Jan)	FROM PRIOR 2 MONTHS (50% of Dec)	FROM PRIOR 3 MONTHS (25% of Nov)	TOTAL
AG	89	99	50	3.75	15.5	2.3	-0.4	-3.5	0.0	0.0	-3.5	1.0	0.6	1.0	2.6
URBAN	87	142	47	3.75	20.9	2.3	0.0	0.0	49.0	0.0	0.0	1.6	1.4	-0.4	2.6
AG	85	354	41	3.75	45.4	2.3	-0.1	-2.6	0.0	0.0	-2.6	7.6	8.0	3.4	19.1
URBAN	83	220	35	3.75	24.1	2.3	0.1	2.5	0.0	0.0	2.5	6.4	6.8	1.1	14.3
OPEN	80	1586	29	3.75	143.7	2.3	0.4	47.9	0.0	0.0	47.9	53.5	61.8	31.4	146.7
AG	78	633	27	3.75	53.4	2.3	0.4	23.1	574.0	20.9	2.2	2.1	2.3	1.2	5.6
OPEN	74	2316	15	3.75	108.6	2.3	0.9	171.3	1169.0	86.5	84.8	51.6	60.2	22.7	134.5
TOTAL		5350			411.4			238.7	1792.0	107.4	131.3	123.9	141.1	60.3	325.3

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - Febuary

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT): FROM PRIOR MONTH (25% of Jan)	FROM PRIOR 2 MONTHS (50% of Dec)	FROM PRIOR 3 MONTHS (25% of Nov)	TOTAL
OPEN	82	319	32	3.75	31.9	2.3	0.3	6.6	69.0	1.4	5.2	8.4	10.4	2.4	21.3
AG	78	350	27	3.75	29.5	2.3	0.4	12.8	117.0	4.3	8.5	8.7	11.3	-0.9	19.1
URBAN	75	69	21	3.75	4.5	2.3	0.7	3.8	1.0	0.1	3.8	2.9	3.3	0.1	6.3
OPEN	74	776	15	3.75	36.4	2.3	0.9	57.4	664.0	49.1	8.3	5.0	6.2	2.2	13.4
TOTAL		1514			102.3			80.6	851.0	54.9	25.7				60.1

Monthly Water Budget for Watsonville Slough - Febuary

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT): FROM PRIOR MONTH (25% of Jan)	FROM PRIOR 2 MONTHS (50% of Dec)	FROM PRIOR 3 MONTHS (25% of Nov)	TOTAL
URBAN	95	1019	72	3.75	229.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
URBAN	92	205	55	3.75	35.2	2.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0
AG	89	200	53	3.75	33.1	2.3	-0.5	-9.0	0.0	0.0	-9.0	2.6	2.1	1.9	6.7
URBAN	87	263	43	3.75	35.3	2.3	0.0	0.0	0.0	0.0	0.0	5.7	4.9	0.0	10.6
AG	85	733	41	3.75	93.9	2.3	-0.1	-5.3	0.0	0.0	-5.3	15.8	16.6	7.1	39.5
URBAN	83	321	32	3.75	32.1	2.3	0.3	6.7	10.0	0.2	6.5	9.3	9.6	0.0	18.9
OPEN	82	927	32	3.75	92.7	2.3	0.3	19.3	0.0	0.0	19.3	31.3	32.3	12.1	75.7
AG	78	79	27	3.75	6.7	2.3	0.4	2.9	124.0	4.5	-1.6	-1.7	-2.0	0.8	-2.9
OPEN	74	57	15	3.75	2.7	2.3	0.9	4.2	0.0	0.0	4.2	2.7	3.2	1.1	7.0
OPEN	61	60	3	3.75	0.6	2.3	1.3	6.7	30.8	3.4	3.3	1.6	2.0	1.2	4.8
TOTAL		3864			561.6			25.5	164.8	8.2	17.3				161.2

Monthly Water Budget for Harkins Slough - March

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Feb)	FROM PRIOR 2 MONTHS (50% of Jan)	FROM PRIOR 3 MONTHS (25% of Dec)	TOTAL
AG	89	99	49	4.5	18.2	3.1	-0.805	-6.6	0	0.0	-6.6	-0.9	2.0	0.3	1.5
URBAN	87	142	42	4.5	22.4	3.1	-0.49	-5.8	49	0.0	-5.8	0.0	3.1	0.7	3.8
AG	85	354	37	4.5	49.1	3.1	-0.265	-7.8	0	0.0	-7.8	-0.6	15.3	4.0	18.6
URBAN	83	220	29	4.5	23.9	3.1	0.095	1.7	0	0.0	1.7	0.6	12.8	3.4	16.8
OPEN	80	1586	24	4.5	142.7	3.1	0.32	42.3	0	0.0	42.3	12.0	107.1	30.9	149.9
AG	78	633	22	4.5	52.2	3.1	0.41	21.6	574	19.6	2.0	0.5	4.2	1.1	5.9
OPEN	74	2316	12	4.5	104.2	3.1	0.86	166.0	1169	83.8	82.2	21.2	103.2	30.1	154.5
TOTAL		5350			412.8			211.4	1792.0	103.4	108.0	32.8	247.7	70.6	351.1

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - March

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Feb)	FROM PRIOR 2 MONTHS (50% of Jan)	FROM PRIOR 3 MONTHS (25% of Dec)	TOTAL
OPEN	82	319	24	4.5	28.7	3.1	0.32	8.5	69	1.8	6.7	1.3	16.9	5.2	23.4
AG	78	350	20	4.5	26.3	3.1	0.5	14.6	117	4.9	9.7	2.1	17.5	5.6	25.2
URBAN	75	69	15	4.5	3.9	3.1	0.725	4.2	1	0.1	4.1	0.9	5.7	1.6	8.3
OPEN	74	776	12	4.5	34.9	3.1	0.86	55.6	664	47.6	8.0	2.1	10.1	3.1	15.2
TOTAL		1514			93.8			82.9	851.0	54.4	28.5	6.4	50.2	15.6	72.2

Monthly Water Budget for Watsonville Slough - March

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Feb)	FROM PRIOR 2 MONTHS (50% of Jan)	FROM PRIOR 3 MONTHS (25% of Dec)	TOTAL
URBAN	95	1019	68	4.5	259.8	3.1	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
URBAN	92	205	55	4.5	42.3	3.1	0	0.0	0	0.0	0.0	0.0	1.9	0.0	1.9
AG	89	200	46	4.5	34.5	3.1	-0.67	-11.2	0	0.0	-11.2	-2.2	5.3	1.1	4.1
URBAN	87	263	37	4.5	36.5	3.1	0	0.0	0	0.0	0.0	0.0	11.3	2.5	13.8
AG	85	733	37	4.5	101.7	3.1	-0.265	-16.2	0	0.0	-16.2	-1.3	31.6	8.3	38.6
URBAN	83	321	28	4.5	33.7	3.1	0	0.0	10	0.0	0.0	1.6	18.7	4.8	25.1
OPEN	82	927	24	4.5	83.4	3.1	0.32	24.7	0	0.0	24.7	4.8	62.6	16.2	83.6
AG	78	79	20	4.5	5.9	3.1	0.5	3.3	124	5.2	-1.9	-0.4	-3.4	-1.0	-4.8
OPEN	74	57	10	4.5	2.1	3.1	0.95	4.5	0	0.0	4.5	1.1	5.3	1.6	8.0
OPEN	61	60	2	4.5	0.5	3.1	1.31	6.6	30.8	3.4	3.2	0.8	3.2	1.0	5.0
TOTAL		3864			600.5			11.7	164.8	8.5	3.2	4.3	136.5	34.4	175.2

Monthly Water Budget for Harkins Slough - April

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Mar)	FROM PRIOR 2 MONTHS (50% of Feb)	FROM PRIOR 3 MONTHS (25% of Jan)	TOTAL
AG	89	99	47	1.5	5.8	1.5	-0.705	-5.8	0	0.0	-5.8	-1.7	-1.8	1.0	-2.4
URBAN	87	142	40	1.5	7.1	1.5	0	0.0	49	0.0	0.0	-1.4	0.0	1.6	0.1
AG	85	354	33	1.5	14.6	1.5	-0.495	-14.6	0	0.0	-14.6	-2.0	-1.3	7.6	4.4
URBAN	83	220	27	1.5	7.4	1.5	0	0.0	0	0.0	0.0	0.4	1.3	6.4	8.1
OPEN	80	1586	20	1.5	39.7	1.5	-0.3	-39.7	0	0.0	-39.7	10.6	24.0	53.5	88.1
AG	78	633	20	1.5	15.8	1.5	-0.3	-15.8	574	0.0	-15.8	0.5	1.1	2.1	3.7
OPEN	74	2316	13	1.5	37.6	1.5	-0.195	-37.6	1169	0.0	-37.6	20.6	42.4	51.6	114.6
TOTAL		**5350**			**128.1**			**-113.5**	**1792.0**	**0.0**	**-113.5**	**27.0**	**65.7**	**123.9**	**216.5**

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - April

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Mar)	FROM PRIOR 2 MONTHS (50% of Feb)	FROM PRIOR 3 MONTHS (25% of Jan)	TOTAL
OPEN	82	319	20	1.5	8.0	1.5	-0.3	-8.0	69	0.0	-8.0	1.7	2.6	8.4	12.7
AG	78	350	13	1.5	5.7	1.5	-0.195	-5.7	117	0.0	-5.7	2.4	4.2	8.7	15.4
URBAN	75	69	13	1.5	1.1	1.5	0	0.0	1	0.0	0.0	1.0	1.9	2.9	5.8
OPEN	74	776	13	1.5	12.6	1.5	-0.195	-12.6	664	0.0	-12.6	2.0	4.1	5.0	11.2
TOTAL		**1514**			**27.4**			**-26.3**	**851.0**	**0.0**	**-26.3**	**7.1**	**12.9**	**25.1**	**45.1**

Monthly Water Budget for Watsonville Slough - April

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Mar)	FROM PRIOR 2 MONTHS (50% of Feb)	FROM PRIOR 3 MONTHS (25% of Jan)	TOTAL
URBAN	95	1019	68	1.5	86.6	1.5	-1.02	-86.6	0	0.0	-86.6	0.0	0.0	0.0	0.0
URBAN	92	205	53	1.5	13.6	1.5	-0.795	-13.6	0	0.0	-13.6	0.0	0.0	1.0	1.0
AG	89	200	40	1.5	10.0	1.5	-0.6	-10.0	0	0.0	-10.0	-2.8	-4.5	2.6	-4.6
URBAN	87	263	33	1.5	10.8	1.5	-0.495	-10.8	0	0.0	-10.8	0.0	0.0	5.7	5.7
AG	85	733	33	1.5	30.2	1.5	-0.495	-30.2	0	0.0	-30.2	-4.0	-2.7	15.8	9.1
URBAN	83	321	27	1.5	10.8	1.5	-0.405	-10.8	10	0.0	-10.8	0.0	3.2	9.3	12.6
OPEN	82	927	20	1.5	23.2	1.5	-0.3	-23.2	0	0.0	-23.2	6.2	9.7	31.3	47.1
AG	78	79	13	1.5	1.3	1.5	-0.195	-1.3	124	0.0	-1.3	-0.5	-0.8	-1.7	-3.0
OPEN	74	57	7	1.5	0.5	1.5	-0.105	-0.5	0	0.0	-0.5	1.1	2.1	2.7	5.9
OPEN	61	60	0	1.5	0.0	1.5	0	0.0	30.8	0.0	0.0	0.8	1.6	1.6	4.0
TOTAL		**3864**			**187.1**			**-187.1**	**164.8**	**0.0**	**-187.1**	**0.8**	**8.7**	**68.3**	**77.7**

Monthly Water Budget for Harkins Slough - May

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Apr)	FROM PRIOR 2 MONTHS (50% of Mar)	FROM PRIOR 3 MONTHS (25% of Feb)	TOTAL
AG	89	99	47	0.4	1.6	0.4	-0.188	-1.6	0	0.0	-1.6	-1.5	-3.3	-0.9	-5.7
URBAN	87	142	40	0.4	1.9	0.4	0	0.0	49	0.0	0.0	0.0	-2.9	0.0	-2.9
AG	85	354	33	0.4	3.9	0.4	-0.132	-3.9	0	0.0	-3.9	-3.7	-3.9	-0.6	-8.2
URBAN	83	220	27	0.4	2.0	0.4	0	0.0	0	0.0	0.0	0.0	0.9	0.6	1.5
OPEN	80	1586	20	0.4	10.6	0.4	-0.08	-10.6	0	0.0	-10.6	-9.9	21.1	12.0	23.2
AG	78	633	20	0.4	4.2	0.4	-0.08	-4.2	574	0.0	-4.2	-4.0	1.0	0.5	-2.4
OPEN	74	2316	13	0.4	10.0	0.4	-0.052	-10.0	1169	0.0	-10.0	-9.4	41.1	21.2	52.9
TOTAL		**5350**			**34.1**			**-30.3**	**1792.0**	**0.0**	**-30.3**	**-28.4**	**54.0**	**32.8**	**58.4**

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough - May

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Apr)	FROM PRIOR 2 MONTHS (50% of Mar)	FROM PRIOR 3 MONTHS (25% of Feb)	TOTAL
OPEN	82	319	0	0.4	0.0	0.4	0	0.0	69	0.0	0.0	-2.0	3.3	1.3	2.6
AG	78	350	0	0.4	0.0	0.4	0	0.0	117	0.0	0.0	-1.4	4.9	2.1	5.6
URBAN	75	69	15	0.4	0.3	0.4	0	-0.3	1	0.0	-0.3	0.0	2.1	0.9	3.0
OPEN	74	776	0	0.4	0.0	0.4	0	0.0	664	0.0	0.0	-3.2	4.0	2.1	2.9
TOTAL		**1514**			**0.3**			**-0.3**	**851.0**	**0.0**	**-0.3**	**-6.6**	**14.3**	**6.4**	**14.1**

Monthly Water Budget for Watsonville Slough - May

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Apr)	FROM PRIOR 2 MONTHS (50% of Mar)	FROM PRIOR 3 MONTHS (25% of Feb)	TOTAL
URBAN	95	1019	68	0.4	23.1	0.4	0	0.0	0	0.0	0.0	-21.7	0.0	0.0	-21.7
URBAN	92	205	55	0.4	3.8	0.4	0	0.0	0	0.0	0.0	-3.4	0.0	0.0	-3.4
AG	89	200	0	0.4	0.0	0.4	0	0.0	0	0.0	0.0	-2.5	-5.6	-2.2	-10.3
URBAN	87	263	37	0.4	3.2	0.4	0	0.0	0	0.0	0.0	-2.7	0.0	0.0	-2.7
AG	85	733	0	0.4	0.0	0.4	0	0.0	0	0.0	0.0	-7.6	-8.1	-1.3	-17.0
URBAN	83	321	28	0.4	3.0	0.4	0	0.0	10	0.0	0.0	-2.7	0.0	1.6	-1.1
OPEN	82	927	0	0.4	0.0	0.4	0	0.0	0	0.0	0.0	-5.8	12.4	4.8	11.4
AG	78	79	0	0.4	0.0	0.4	0	0.0	124	0.0	0.0	-0.3	-0.9	-0.4	-1.7
OPEN	74	57	0	0.4	0.0	0.4	0	0.0	0	0.0	0.0	-0.1	2.3	1.1	3.2
OPEN	61	60	0	0.4	0.0	0.4	0	0.0	30.8	0.0	0.0	0.0	1.6	0.8	2.4
TOTAL		**3864**			**33.1**			**0.0**	**164.8**	**0.0**	**0.0**	**-46.8**	**1.6**	**4.3**	**-40.8**

Monthly Water Budget for Harkins Slough -June

												SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT)			
CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	FROM PRIOR MONTH (25% of May)	FROM PRIOR 2 MONTHS (50% of Apr)	FROM PRIOR 3 MONTHS (25% of Mar)	TOTAL
AG	89	99	47	0	0.0	0	0	0.0	0	0.0	0.0	-0.4	-2.9	-1.7	-5.0
URBAN	87	142	40	0	0.0	0	0	0.0	49	0.0	0.0	0.0	0.0	-1.4	-1.4
AG	85	354	33	0	0.0	0	0	0.0	0	0.0	0.0	-1.0	-7.3	-2.0	-10.2
URBAN	83	220	27	0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.4	0.4
OPEN	80	1586	20	0	0.0	0	0	0.0	0	0.0	0.0	-2.6	-19.8	10.6	-11.9
AG	78	633	20	0	0.0	0	0	0.0	574	0.0	0.0	-1.1	-7.9	0.5	-8.5
OPEN	74	2316	13	0	0.0	0	0	0.0	1169	0.0	0.0	-2.5	-18.8	20.6	-0.8
TOTAL		5350			0.0			0.0	1792.0	0.0	0.0	-7.6	-56.8	27.0	-37.3

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough -June

												SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT)			
CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	FROM PRIOR MONTH (25% of May)	FROM PRIOR 2 MONTHS (50% of Apr)	FROM PRIOR 3 MONTHS (25% of Mar)	TOTAL
OPEN	82	319	0	0	0.0	0	0	0.0	69	0.0	0.0	0.0	-4.0	1.7	-2.3
AG	78	350	0	0	0.0	0	0	0.0	117	0.0	0.0	0.0	-2.8	2.4	-0.4
URBAN	75	69	0	0	0.0	0	0	0.0	1	0.0	0.0	-0.1	0.0	1.0	0.9
OPEN	74	776	0	0	0.0	0	0	0.0	664	0.0	0.0	0.0	-6.3	2.0	-4.3
TOTAL		1514			0.0			0.0	851.0	0.0	0.0	-0.1	-13.1	7.1	-6.1

Monthly Water Budget for Watsonville Slough -June

												SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT)			
CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	FROM PRIOR MONTH (25% of May)	FROM PRIOR 2 MONTHS (50% of Apr)	FROM PRIOR 3 MONTHS (25% of Mar)	TOTAL
URBAN	95	1019	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-43.3	0.0	-43.3
URBAN	92	205	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-6.8	0.0	-6.8
AG	89	200	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-5.0	-2.8	-7.8
URBAN	87	263	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-5.4	0.0	-5.4
AG	85	733	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-15.1	-4.0	-19.2
URBAN	83	321	0	0	0.0	0	0	0.0	10	0.0	0.0	0.0	-5.4	0.0	-5.4
OPEN	82	927	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-11.6	6.2	-5.4
AG	78	79	0	0	0.0	0	0	0.0	124	0.0	0.0	0.0	-0.6	-0.5	-1.1
OPEN	74	57	0	0	0.0	0	0	0.0	0	0.0	0.0	0.0	-0.2	1.1	0.9
OPEN	61	60	0	0	0.0	0	0	0.0	30.8	0.0	0.0	0.0	0.0	0.8	0.8
TOTAL		3864			0.0			0.0	164.8	0.0	0.0	0.0	-93.5	0.8	-92.7

Monthly Water Budget for Harkins Slough -July

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT FROM PRIOR MONTH (25% of Aug)	FROM PRIOR 2 MONTHS (50% of Jul)	FROM PRIOR 3 MONTHS (25% of Jun)	TOTAL
AG	89	99	47	0	0.0	0.62	-0.62	-5.1	0	0.0	-5.1	0.0	-0.8	-1.5	-2.2
URBAN	87	142	40	0	0.0	0.62	-0.62	-7.3	49	0.0	-7.3	0.0	0.0	0.0	0.0
AG	85	354	33	0	0.0	0.62	-0.62	-18.3	0	0.0	-18.3	0.0	-1.9	-3.7	-5.6
URBAN	83	220	27	0	0.0	0.62	-0.62	-11.4	0	0.0	-11.4	0.0	0.0	0.0	0.0
OPEN	80	1586	20	0	0.0	0.62	-0.62	-81.9	0	0.0	-81.9	0.0	-5.3	-9.9	-15.2
AG	78	633	20	0	0.0	0.62	-0.62	-32.7	574	0.0	-32.7	0.0	-2.1	-4.0	-6.1
OPEN	74	2316	13	0	0.0	0.62	-0.62	-119.7	1169	0.0	-119.7	0.0	-5.0	-9.4	-14.4
TOTAL		5350			0.0			-276.4	1792.0	0.0	-276.4				-43.5

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough -July

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT FROM PRIOR MONTH (25% of Aug)	FROM PRIOR 2 MONTHS (50% of Jul)	FROM PRIOR 3 MONTHS (25% of Jun)	TOTAL
OPEN	82	319	0	0	0.0	0.62	-0.62	-16.5	69	0.0	-16.5	0.0	0.0	-2.0	-2.0
AG	78	350	0	0	0.0	0.62	-0.62	-18.1	117	0.0	-18.1	0.0	0.0	-1.4	-1.4
URBAN	75	69	0	0	0.0	0.62	-0.62	-3.6	1	0.0	-3.6	0.0	-0.2	0.0	-0.2
OPEN	74	776	0	0	0.0	0.62	-0.62	-40.1	664	0.0	-40.1	0.0	0.0	-3.2	-3.2
TOTAL		1514			0.0			-78.2	851.0	0.0	-78.2				-6.7

Monthly Water Budget for Watsonville Slough -July

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH. ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT FROM PRIOR MONTH (25% of Aug)	FROM PRIOR 2 MONTHS (50% of Jul)	FROM PRIOR 3 MONTHS (25% of Jun)	TOTAL
URBAN	95	1019	0	0	0.0	0.62	-0.62	-52.6	0	0.0	-52.6	0.0	0.0	-21.7	-21.7
URBAN	92	205	0	0	0.0	0.62	-0.62	-10.6	0	0.0	-10.6	0.0	0.0	-3.4	-3.4
AG	89	200	0	0	0.0	0.62	-0.62	-10.3	0	0.0	-10.3	0.0	0.0	-2.5	-2.5
URBAN	87	263	0	0	0.0	0.62	-0.62	-13.6	0	0.0	-13.6	0.0	0.0	-2.7	-2.7
AG	85	733	0	0	0.0	0.62	-0.62	-37.9	0	0.0	-37.9	0.0	0.0	-7.6	-7.6
URBAN	83	321	0	0	0.0	0.62	-0.62	-16.6	10	0.0	-16.6	0.0	0.0	-2.7	-2.7
OPEN	82	927	0	0	0.0	0.62	-0.62	-47.9	0	0.0	-47.9	0.0	0.0	-5.8	-5.8
AG	78	79	0	0	0.0	0.62	-0.62	-4.1	124	0.0	-4.1	0.0	0.0	-0.3	-0.3
OPEN	74	57	0	0	0.0	0.62	-0.62	-2.9	10	0.0	-2.9	0.0	0.0	-0.1	-0.1
OPEN	61	60	0	0	0.0	0.62	-0.62	-3.1	30.8	0.0	-3.1	0.0	0.0	0.0	0.0
TOTAL		3864			0.0			-199.6	174.8	0.0	-199.6				-46.8

Monthly Water Budget for Harkins Slough -August

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Jul)	FROM PRIOR 2 MONTHS (50% of Jun)	FROM PRIOR 3 MONTHS (25% of Apr)	TOTAL
AG	89	99	47	0	0.0	0	0	0.0	0	0.0	0.0	-1.3	0.0	-0.4	-1.7
URBAN	87	142	40	0	0.0	0	0	0.0	49	0.0	0.0	-1.8	0.0	0.0	-1.8
AG	85	354	33	0	0.0	0	0	0.0	0	0.0	0.0	-4.6	0.0	-1.0	-5.5
URBAN	83	220	27	0	0.0	0	0	0.0	0	0.0	0.0	-2.8	0.0	0.0	-2.8
OPEN	80	1586	20	0	0.0	0	0	0.0	0	0.0	0.0	-20.5	0.0	-2.6	-23.1
AG	78	633	20	0	0.0	0	0	0.0	574	0.0	0.0	-8.2	0.0	-1.1	-9.2
OPEN	74	2316	13	0	0.0	0	0	0.0	1169	0.0	0.0	-29.9	0.0	-2.5	-32.4
TOTAL		5350			0.0			0.0	1792.0	0.0	0.0				-76.7

Notes:
1. Percent runoff derived from TR-55 modeling
2. Determined from actual measurements at the Watsonville Water Works

Monthly Water Budget for Gallighan Slough -August

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Jul)	FROM PRIOR 2 MONTHS (50% of Jun)	FROM PRIOR 3 MONTHS (25% of Apr)	TOTAL
OPEN	82	319	47	0	0.0	0	0	0.0	69	0.0	0.0	-4.1	0.0	0.0	-4.1
AG	78	350	40	0	0.0	0	0	0.0	117	0.0	0.0	-4.5	0.0	0.0	-4.5
URBAN	75	69	33	0	0.0	0	0	0.0	1	0.0	0.0	-0.9	0.0	-0.1	-1.0
OPEN	74	776	13	0	0.0	0	0	0.0	664	0.0	0.0	-10.0	0.0	0.0	-10.0
TOTAL		1514			0.0			0.0	851.0	0.0	0.0				-19.6

Monthly Water Budget for Watsonville Slough -August

CATEGORY	CN	ACRES	% R.O.	AVE. PRECIP. (INCHES)	TOTAL RUNOFF (AC-FT)	ET (IN)	DEEP PERCOLATION (IN)	DEEP PERCOLATION (AC-FT)	AREA OVER DEEP RECH ZONE(AC)	DEEP GW RECH. (AC-FT)	SHALLOW GW RECH. (AC-FT)	SHALLOW GW DISCHARGE TO SLOUGHS (AC-FT) FROM PRIOR MONTH (25% of Jul)	FROM PRIOR 2 MONTHS (50% of Jun)	FROM PRIOR 3 MONTHS (25% of Apr)	TOTAL
URBAN	95	1019	0	0	0.0	0	0	0.0	0	0.0	0.0	-13.2	0.0	0.0	-13.2
URBAN	92	205	0	0	0.0	0	0	0.0	0	0.0	0.0	-2.6	0.0	0.0	-2.6
AG	89	200	0	0	0.0	0	0	0.0	0	0.0	0.0	-2.6	0.0	0.0	-2.6
URBAN	87	263	0	0	0.0	0	0	0.0	0	0.0	0.0	-3.4	0.0	0.0	-3.4
AG	85	733	0	0	0.0	0	0	0.0	0	0.0	0.0	-9.5	0.0	0.0	-9.5
URBAN	83	321	0	0	0.0	0	0	0.0	10	0.0	0.0	-4.1	0.0	0.0	-4.1
OPEN	82	927	0	0	0.0	0	0	0.0	0	0.0	0.0	-12.0	0.0	0.0	-12.0
AG	78	79	0	0	0.0	0	0	0.0	124	0.0	0.0	-1.0	0.0	0.0	-1.0
OPEN	74	57	0	0	0.0	0	0	0.0	0	0.0	0.0	-0.7	0.0	0.0	-0.7
OPEN	61	60	0	0	0.0	0	0	0.0	30.8	0.0	0.0	-0.8	0.0	0.0	-0.8
TOTAL		3864			0.0			0.0	164.8	0.0	0.0				-49.9

Table 5-3D. OVERALL WATER BUDGET FOR THE WATSONVILLE SLOUGH SYSTEM FOR AN DRY YEAR (1986-1987) AT THE SHELL ROAD PUMP STATION

MONTH	PRECIP (IN)	PRECIP (AC-FT)	RUNOFF (AC-FT)	GW SEEPAGE LOST (AC-FT)	LOSS TO DEEP GW (AC-FT)	RETURN SHALLOW GW (AC-FT)	SEPTIC RETURN (AC-FT)	AG RETURN (AC-FT)	ET LOSS FROM SEASONAL WETLANDS (AC-FT)	OUTFLOW OF SLOUGH SYSTEM (AC-FT)
SEPT	1.2	1091.0	109.8	6	206.1	-338.6	3.0	188.1	43.7	257.2
OCT	0.09	81.8	8.2	6	0.0	-76.6	3.0	117.0	22.1	106.2
NOV	0.06	54.6	7.9	6	0.0	12.4	3.0	0.0		17.3
DEC	1.27	1154.6	299.9	6	0.0	-879.5	3.0	0.0		302.9
JAN	3.24	2945.7	797.0	6	219.4	-1135.2	3.0	0.0		800.0
FEB	5.17	4700.4	1482.6	6	435.2	-571.1	3.0	0.0		1485.6
MAR	2.88	2618.4	708.5	6	0.0	224.0	3.0	0.0		929.5
APR	0.46	418.2	105.0	6	0.0	275.8	3.0	131.0		508.8
MAY	0	0.0	0.0	6	0.0	-389.9	3.0	154.6	160.5	-2.9
JUN	0.02	18.2	1.7	6	4.2	-724.4	3.0	227.1	157.3	74.5
JUL	0	0.0	0.0	6	0.0	-384.5	3.0	218.7	152.5	69.2
AUG	0	0.0	0.0	6	0.0	-202.2	3.0	107.3	72.2	38.0
TOTAL	**14.39**	**13082.9**	**3520.8**	**72.0**	**864.9**	**-2475.9**	**36.0**	**1143.7**	**608.4**	**4586.3**

Table 5-3w. OVERALL WATER BUDGET FOR THE WATSONVILLE SLOUGH SYSTEM FOR A WET WATER YEAR (1981-82)AT THE SHELL ROAD PUMP STATION

MONTH	PRECIP (IN)	PRECIP (AC-FT)	RUNOFF (AC-FT)	GW SEEPAGE LOST (AC-FT)	LOSS TO DEEP GW (AC-FT)	RETURN SHALLOW GW (AC-FT)	SEPTIC RETURN (AC-FT)	AG RETURN (AC-FT)	ET LOSS FROM SEASONAL WETLANDS (AC-FT)	OUTFLOW OF SLOUGH SYSTEM (AC-FT)
SEPT	0.02	18.2	1.8	6	0.0	-266.0	3.0	188.1	48.1	144.8
OCT	1.84	1672.9	168.4	6	170.6	-218.8	3.0	117.0	24.3	264.2
NOV	6.37	5791.4	1303.0	6	677.9	-5.5	3.0	0.0		1306.0
DEC	3.88	3527.6	916.3	6	401.2	804.2	3.0	0.0		1717.5
JAN	10.53	9573.5	2590.4	6	1660.8	1060.0	3.0	0.0		3647.4
FEB	4.42	4018.5	1267.5	6	295.3	1622.3	3.0	0.0		2886.8
MAR	6.38	5800.5	1569.5	6	534.9	2002.9	3.0	0.0		3569.4
APR	5.58	5073.2	1274.2	6	751.2	1281.8	3.0	0.0		2552.9
MAY	0	0.0	0.0	6	0.0	919.9	3.0	154.6	176.6	895.0
JUN	0.38	345.5	32.4	6	79.8	912.7	3.0	227.1	173.0	996.1
JUL	0	0.0	0.0	6	0.0	301.0	3.0	218.7	167.8	349.0
AUG	0	0.0	0.0	6	0.0	-94.5	3.0	107.3	79.5	30.8
TOTAL	**39.4**	**35821.2**	**9123.5**	**72.0**	**4571.8**	**7691.1**	**36.0**	**1012.8**	**669.2**	**18359.9**

NORMAL CROP WATER USE[1]
CENTRAL COASTAL PLAINS[2]
EVAPOTRANSPIRATION (CONSUMPTIVE USE) TABLE

ESTIMATED MONTHLY EVAPOTRANSPIRATION (inches)[4]

Crop and Growing Period[3]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Artichokes													
6/15 – 4/15	1.7	2.2	3.1	1.8		.7	2.1	3.0	3.5	3.2	2.2	1.4	24.9
7/1 – 5/1	1.7	2.2	3.1	3.8			1.7	2.4	3.0	3.2	2.2	1.4	24.6
7/15 – 5/15	1.7	2.2	3.1	3.8	2.1		.8	1.9	2.5	2.9	2.2	1.4	24.6
Broccoli													
2/1 – 5/15		1.4	2.5	3.9	2.2								10.0
3/15 – 7/1			.9	2.3	4.3	4.9							12.4
8/15 – 12/1								1.1	2.1	3.0	2.2		8.4
10/15 – 3/1	1.8	2.2								.9	1.4	1.4	7.7
Brussels Sprouts													
4/15 – 8/15				.9	2.6	4.6	5.3	2.3					15.7
7/15 – 3/1	1.8	2.2					1.2	2.4	3.4	3.3	2.2	1.5	18.0
Carrots													
12/1 – 3/31	1.5	2.3	3.3									1.0	8.1
1/15 – 5/15	.5	1.4	3.1	4.1	2.3								11.4
7/15 – 12/15							1.1	2.5	3.4	3.5	2.3	.8	13.6
Cauliflower													
5/15 – 8/1					1.1	3.2	5.2						9.5
8/1 – 11/15								2.1	3.4	3.3	1.2		10.0
12/1 – 5/1	1.5	2.2	3.1	3.9								1.0	11.7
Celery													
1/15 – 7/1	.6	1.5	2.9	4.1	4.9	5.1							19.1
8/1 – 1/1								2.0	2.5	3.2	2.3	1.5	11.5
Cucumbers													
3/15 – 6/15			.8	2.1	4.1	2.2							9.2
7/1 – 8/31							2.9	4.4					7.3
Lettuce													
12/15 – 4/15	1.6	2.1	3.1	1.8								.6	9.2
3/15 – 7/15			1.3	3.1	4.4	4.8	2.5						16.1
8/15 – 11/15								1.7	3.2	3.2	1.2		9.3
Onions													
2/15 – 9/15		.7	2.0	3.7	4.7	4.9	5.3	4.7	1.8				27.8
3/1 – 10/1			1.7	3.0	4.6	4.9	5.3	4.8	3.6				27.9
3/15 – 10/15			.9	2.3	4.4	4.9	5.3	4.8	3.9	1.5			28.0
Peppers													
2/15 – 9/1		.7	2.0	3.6	4.7	4.9	5.3	4.6					25.8
4/1 – 11/1				1.8	3.1	4.7	5.3	4.8	3.9	3.1			26.7
Potatoes													
4/1 – 8/31				2.4	4.9	6.1	6.4	3.2					23.0
6/15 – 12/1						1.4	4.2	5.7	4.8	4.1	1.6		21.8
Spinach													
9/15 – 11/15									.9	2.4	1.2		4.5
11/15 – 1/31	1.7										.6	1.2	3.5
1/15 – 4/15	.6	1.8	3.1	1.8									7.3
Tomatoes													
3/1 – 7/31			.8	1.5	4.4	5.8	5.0						17.5
5/1 – 10/15					1.2	1.9	5.0	5.7	4.3	1.6			19.7

1/ Estimated evapotranspiration (Consumptive Use) data were obtained from historic measurements, and from calculations based on data in Figure 8, Table 22 and 23, Crop Water Requirements, No. 24 Food and Agricultural Organization of the United Nations.

2/ Coastal areas of San Mateo, Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara Counties.

3/ Planting to harvest.

4/ Other crops which have similar growing seasons, ground cover, and growth characteristics have similar ET requirements.

NORMAL CROP WATER USE [1/]

CENTRAL COAST INTERIOR VALLEYS [2/]

EVAPOTRANSPIRATION (CONSUMPTIVE USE) TABLE

ESTIMATED MONTHLY EVAPOTRANSPIRATION (inches) [4/]

Crop and Growing Period [3/]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Pasture – annual [5/]	1.6	2.1	3.4	4.4	5.7	6.2	6.8	6.0	4.8	3.7	2.3	1.4	48.4
				0.241	0.442	0.508	0.558	0.495	0.375	0.217			
Alfalfa – annual	1.7	2.2	3.3	4.3	5.5	6.1	6.8	5.9	4.7	3.7	2.4	1.6	48.0
Deciduous Orchard [6/] with cover crop – annual	1.6	2.1	3.4	4.8	6.5	7.5	8.2	7.2	5.8	4.1	2.3	1.5	54.8
Deciduous Orchard [6/] without cover crop													
3/1 – 10/31			2.0	3.2	4.7	5.7	6.5	6.7	4.4	2.9			35.1
3/15 – 11/15			1.0	2.9	4.4	5.4	6.5	5.7	4.6	3.2	1.0		34.7
3/30 – 11/30				2.6	4.0	5.2	6.2	5.7	4.7	3.5	1.9		33.8
Grapes [7/]													
3/1 – 10/31			.7	2.6	4.5	5.1	5.0	3.1	1.4	.5			22.9
4/15 – 11/15				.5	2.1	4.3	5.5	3.8	1.9	.7	.2		19.0
5/1 – 11/30					1.2	3.6	5.3	4.5	2.5	1.1	.3		18.5

1/ Estimated evapotranspiration (Consumptive Use) data were obtained from historic measurements, and from calculations based on data in Figure 8, Table 22 and 23, Crop Water Requirements: No. 24 Food and Agricultural Organization of the United Nations.

2/ Interior portions of Contra Costa, Alameda, Santa Clara, San Benito, Monterey, San Luis Obispo, Santa Barbara and Ventura Counties.

3/ Leaf out to leaf drop. Where applicable values shown are for mature trees and vines. For smaller trees and vines consult local Agriculture Extension or S.C.S. Office for appropriate ET reductions.

4/ Other crops which have similar growing seasons, ground cover, and growth characteristics have similar ET requirements.

5/ Pasture – based on well managed pasture with animals removed before significant elimination of shading of ground surface.

6/ For deciduous trees where irrigation is ended before harvest, water use during the later part of the growing season will be less than values shown.

7/ Wine grapes.

APPENDIX D

BACKGROUND WATER QUALITY
AND
TISSUE ANALYSIS DATA

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APPENDIX D

Organic Chemicals Present in Tissue Table

Summary of State Mussel Watch Program and Toxic Substance Monitoring Program Water Quality Monitoring Results for the Watsonville Slough System

The following table summarizes the results of water quality testing under the State Mussel Watch (SMW) Program and the Toxic Substances Monitoring (TSM) Program in the Watsonville Slough system. Both of these programs have been carried out by the State Water Resources Control Board.

The SMW Program sampled water quality in various locations throughout the slough system between the years 1982 and 1993. The TSM Program sampled locations in the Watsonville Slough system each year between 1984 and 1988.

The acronyms/abbreviations used in the following table are defined as follows:

NAS = National Academy of Sciences. The National Academy of Sciences has established recommended maximum concentrations of toxic substances in fish and shellfish tissue (NAS 1973). They were established not only to protect the organisms containing these toxic compounds, but also the species that consume these contaminated organisms (including humans).

EDL 85 = Elevated Data Level, 85th percentile. This refers to a pollutant level finding that is "markedly elevated" from the median value of all sampling results from throughout California over the life of the program. These results indicate pollutant levels that are in the upper 85th percentile of all results statewide.

EDL 95 = Elevated Data Level, 95th percentile. This refers to a pollutant level finding that is "highly elevated" from the median value of all sampling results from throughout California over the life of the program. These results indicate pollutant levels that are in the upper 95th percentile of all results statewide, which would represent two standard deviations above the mean if the data were normally distributed.

Organic Chemicals Present in Tissue
(ug/kg [ppb] wet weight)

Station Number	Station - Location Name	Sample Date (y/m/d)	Species Name	Aldrin	Total Chlordane	Alpha-Chlordene	Cis-Chlordene	Gamma-Chlordene	Trans-Chlordane	Oxy-Chlordane
Data from SWRCB Mussel Watch										
A21	Harkins Slough at Harkins Slough Road Bridge	88/02/02	TFC	ND	12.6	ND	7.4	ND	1.6	ND
		86/11/26	FWC	ND	5.3	**0.3**	0.2	**1.5**	2.0	ND
A32	Watsonville Slough above Harkins Slough Pump	88/02/03	TFC	0.7	21.4	0.4	7.0	0.8	5.4	1.3
		86/11/26	FWC	ND	**33.0**	**1.2**	**12.0**	**0.7**	8.2	ND
		85/12/06	FWC	0.8	**24.8**	**0.7**	**7.9**	**1.1**	6.8	ND
A40	Watsonville Slough at Pajaro River confluence	89/11/17	TCM	NA	NA	NA	NA	NA	NA	NA
		86/01/27	TCM	ND	13.0	ND	4.3	ND	3.9	0.3
		83/11/28	TCM	ND	22.5	0.5	19.5	**0.8**	7.3	ND
		82/11/17	TCM	NA	NA	NA	NA	NA	NA	NA
A41	Watsonville Slough at Shell Road	93/03/10	TFC	1.0	49.4	0.7	12.0	0.9	11.0	0.8
		88/02/02	TFC	1.0	31.4	1.0	8.4	1.4	9.4	1.6
Data from SWRCB Toxic Substances Monitoring Program										
A23	Harkins Slough Upstream of Watsonville Slough	88/07/28	STB-W	<5.0	70.4	<5.0	17.0	<5.0	11.0	<5.0
		88/07/28	STB-W	<5.0	67.6	<5.0	23.0	<5.0	**12.0**	<5.0
		85/06/05	CP-F	<5.0	**208.0**	**9.0**	**55.0**	**6.0**	**40.0**	**22.0**
		85/06/05	SBF-F	<5.0	58.2	<5.0	**19.0**	<5.0	14.0	<5.0
A31	Watsonville Slough at San Andreas Road	85/06/05	STB-W	<5.0	**195.8**	**6.8**	60.0	10.0	36.0	14.0
		84/06/15	STB-W	<5.0	**278.7**	5.7	70.0	<5.0	**50.0**	**23.0**
A32	Watsonville Slough above Harkins Slough Pump	85/06/05	CP-W	<5.0	95.0	<5.0	30.0	<5.0	22.0	10.0
		85/06/05	GAM-W	<5.0	58.0	<5.0	<5.0	<5.0	8.0	14.0
A34	Watsonville Slough at Lee Road	88/07/28	SBF-F	<5.0	6.0	<5.0	<5.0	<5.0	<5.0	<5.0
A42	Watsonville Slough at Harkins Slough Road	86/10/02	STB-W	<5.0	**287.5**	<5.0	**86.0**	9.0	42.0	6.5

< = below indicated detection limit
TCM = Transplanted California Mussel
TFC = Transplanted Freshwater Clam
FWC = Freshwater Clam
CP = Crappie (*Pomoxis sp.*)

GAM = Mosquito fish
SBF = Sacramento Blackfish
STB = Threespine Stickleback
F = filet
W = whole body

Exceeds NAS Recommendations
Exceeds EDL 85
Exceeds EDL 95

APPENDIX D

Organic Chemicals Present in Tissue
(ug/kg [ppb] wet weight)

Station Number	Sample Date (y/m/d)	Cis-Nonachlor	Trans-Nonachlor	Chlorpyrifos	Dachthal	Total DDT	OP'DDD	PP'DDD	OP'DDE	PP'DDE	PP'DDMU	PP'DDMS	OP'DDT
Data from SWRCB Mussel Watch													
A21	88/02/02	1.1	2.4	ND	0.6	40.3	4.8	5.0	0.8	19.2	ND	ND	1.8
	86/11/26	ND	1.4	ND	0.9	*27.9*	*3.4*	5.8	*0.8*	*15.2*	ND	ND	**0.8**
A32	88/02/03	ND	6.5	ND	7.2	437.0	21.6	51.3	*10.8*	198.0	8.2	*4.9*	*43.2*
	86/11/26	**0.8**	**10.2**	ND	**4.3**	**1445.0**	**79.2**	**195.2**	**9.4**	**1044.0**	7.1	ND	**25.2**
	85/12/06	**2.9**	**5.3**	ND	**10.8**	**608.4**	**28.8**	**60.5**	7.2	**230.4**	7.9	ND	**43.2**
A40	89/11/17	NA	NA	NA	NA	**1615.0**	**85.0**	NA	NA	NA	NA	NA	NA
	86/01/27	1.2	3.2	ND	*5.6*	*240.2*	*11.7*	*38.9*	3.9	*136.1*	*6.5*	ND	**8.8**
	83/11/28	ND	3.5	ND	**137.8**	**538.5**	**34.9**	**126.2**	5.3	**265.6**	5.3	ND	**11.6**
	82/11/17	NA	NA	NA	NA	*239.0*	**14.1**	*63.6*	2.7	*130.2*	5.2	ND	5.5
A41	93/03/10	**13.0**	*11.0*	12.0	21.0	**1059.1**	45.0	64.0	*13.0*	*500.0*	*19.0*	*7.1*	*110.0*
	88/02/02	2.6	7.0	2.6	4.9	359.8	22.0	55.0	7.2	150.0	4.0	**8.6**	31.0
Data from SWRCB Toxic Substances Monitoring Program													
A23	88/07/28	7.4	35.0	<10.0	8.8	**3528.0**	120.0	300.0	*48.0*	2500.0	*120.0*	<30.0	*100.0*
	88/07/28	8.6	24.0	<10.0	9.1	**3780.0**	*140.0*	340.0	*49.0*	*2700.0*	*120.0*	<30.0	*100.0*
	85/06/05	**20.0**	**56.0**	<10.0	<5.0	**2623.0**	**120.0**	**570.0**	*26.0*	*1700.0*	**77.0**	<30.0	**31.0**
	85/06/05	7.2	18.0	<10.0	<5.0	**1098.0**	*27.0*	*160.0*	*13.0*	*860.0*	*24.0*	<30.0	*14.0*
A31	85/06/05	17.0	52.0	<10.0	9.0	**8684.0**	**270.0**	*830.0*	**64.0**	*4100.0*	**470.0**	<30.0	*210.0*
	84/06/15	<5.0	**130.0**	<10.0	11.0	**10020.0**	**600.0**	**2200.0**	**180.0**	*5300.0*	**560.0**	<30.0	**280.0**
A32	85/06/05	11.0	22.0	<10.0	8.4	**3815.0**	**310.0**	*1200.0*	*40.0*	1800.0	*170.0*	<30.0	*65.0*
	85/06/05	12.0	24.0	<10.0	<5.0	**4488.0**	*150.0*	*1200.0*	29.0	2400.0	**360.0**	<30.0	29.0
A34	88/07/28	<5.0	6.0	<10.0	<5.0	**560.0**	20.0	110.0	<10.0	430.0	< 15.0	<30.0	<10.0
A42	86/10/02	**51.0**	*93.0*	<10.0	34.0	*404.0*	37.0	80.0	<10.0	230.0	20.0	<30.0	<10.0

< = below indicated detection limit

Exceeds NAS Recommendations

Exceeds EDL 85

Exceeds EDL 95

Organic Chemicals Present in Tissue
(ug/kg [ppb] wet weight)

Station Number	Sample Date (y/m/d)	PP'DDT	Diazinon	Dichloroben-zophenone	Dieldrin	Endrin	Total Endosulfan	ES I	ES II	Endosulfan sulfate	Hexachloro-benzene	a-HCH	b-HCH	g-HCH
Data from SWRCB Mussel Watch														
A21	88/02/02	8.8	ND	**6.2**	2.3	ND	1.6	1.6	ND	ND	NA	ND	ND	ND
	86/11/26	2.0	ND	NA	**2.9**	ND	*8.0*	**8.0**	ND	ND	0.2	ND	ND	ND
A32	88/02/03	99.0	ND	ND	*126.0*	4.4	36.5	7.3	8.6	20.7	NA	ND	ND	ND
	86/11/26	**88.8**	ND	NA	**324.0**	**16.8**	**84.0**	**24.0**	**21.6**	**38.4**	**1.0**	ND	ND	ND
	85/12/06	**230.4**	**19.4**	NA	**136.8**	**5.3**	**35.4**	**17.3**	**11.5**	**6.6**	*0.3*	ND	ND	ND
A40	89/11/17	**120.0**	NA	NA	NA	NA	**400.0**	NA	NA	NA	NA	NA	NA	NA
	86/01/27	**34.6**	ND	NA	**30.2**	**2.6**	**295.9**	**155.5**	**47.5**	**92.9**	ND	*0.7*	ND	ND
	83/11/28	**89.6**	ND	NA	**38.8**	**7.3**	**562.7**	**298.8**	**127.8**	**136.1**	ND	**1.1**	ND	**1.1**
	82/11/17	*17.8*	NA	NA	NA	NA	**59.2**	**59.2**	NA	NA	NA	NA	NA	NA
A41	93/03/10	*300.0*	NA	ND	*170.0*	*18.0*	40.1	3.1	15.0	22.0	0.7	ND	ND	*0.7*
	88/02/02	82.0	**110.0**	*4.0*	75.0	5.8	58.0	22.0	16.0	20.0	NA	*0.1*	ND	0.2
Data from SWRCB Toxic Substances Monitoring Program														
A23	88/07/28	*340.0*	<50.0	NA	**580.0**	16.0	**372.0**	*52.0*	**80.0**	*240.0*	2.7	<2.0	<10.0	<2.0
	88/07/28	*350.0*	**63.0**	NA	**620.0**	18.0	**412.0**	**58.0**	**84.0**	*270.0*	3.7	<2.0	<10.0	<2.0
	85/06/05	*99.0*	<50.0	NA	240.0	43.0	252.0	**47.0**	*95.0*	**110.0**	2.7	<2.0	<10.0	<2.0
	85/06/05	<10.0	<50.0	NA	**62.0**	<15.0	ND	<5.0	<70.0	<85.0	<2.0	<2.0	<10.0	<2.0
A31	85/06/05	*720.0*	<50.0	NA	**960.0**	<15.0	261.0	*17.0*	24.0	*220.0*	4.8	<2.0	<10.0	<2.0
	84/06/15	**900.0**	<50.0	NA	**1700.0**	*48.0*	242.0	*22.0*	<70.0	*220.0*	5.0	**2.1**	<10.0	<2.0
A32	85/06/05	*230.0*	<50.0	NA	**460.0**	*27.0*	13.0	13.0	<70.0	<85.0	<2.0	<2.0	<10.0	<2.0
	85/06/05	*300.0*	<50.0	NA	**610.0**	20.0	ND	<5.0	<70.0	<85.0	<2.0	<2.0	<10.0	<2.0
A34	88/07/28	<10.0	<50.0	NA	11.0	<15.0	**189.0**	<5.0	*79.0*	**120.0**	<2.0	<2.0	<10.0	<2.0
A42	86/10/02	*37.0*	<50.0	NA	42.0	<15.0	ND	<5.0	<70.0	<85.0	4.0	<2.0	<10.0	<2.0

< = below indicated detection limit

Exceeds NAS Recommendations

Exceeds EDL 85

Exceeds EDL 95

APPENDIX D

Organic Chemicals Present in Tissue
(ug/kg [ppb] wet weight)

Station Number	Sample Date (y/m/d)	d-HCH	Total HCH	Heptachlor	Hepachlor epoxide	Methoxy chlor	Methyl parathion	Oxydiazon	Total PCB	PCB 48	PCB 54	PCB 60	Toxaphene
Data from SWRCB Mussel Watch													
A21	88/02/02	ND	ND	**0.3**	*1.0*	ND	**1.8**	NA	ND	ND	ND	ND	ND
	86/11/26	ND	ND	ND	ND	ND	ND	NA	5.8	ND	5.8	ND	13.8
A32	88/02/03	ND	ND	ND	*2.0*	ND	ND	NA	16.2	ND	16.2	ND	279.0
	86/11/26	ND	ND	ND	ND	ND	ND	NA	*20.4*	ND	*20.4*	ND	**1342.0**
	85/12/06	ND	ND	**0.2**	ND	**20.2**	ND	NA	*27.4*	ND	*27.4*	ND	**597.6**
A40	89/11/17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**950.0**
	86/01/27	ND	0.7	ND	**0.8**	ND	ND	NA	10.4	ND	10.4	ND	*67.0*
	83/11/28	ND	2.2	ND	**1.0**	ND	ND	NA	14.4	ND	14.4	NA	**215.8**
	82/11/17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**140.6**
A41	93/03/10	ND	0.7	ND	**2.6**	ND	NA	*28.0*	27.0	7.9	19.0	ND	*1500.0*
	88/02/02	ND	0.3	**0.3**	**3.0**	**2.4**	ND	NA	13.0	ND	13.0	ND	460.0
Data from SWRCB Toxic Substances Monitoring Program													
A23	88/07/28	<5.0	ND	<5.0	<5.0	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	*820.0*
	88/07/28	<5.0	ND	<5.0	*14.0*	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	*930.0*
	85/06/05	<5.0	ND	<5.0	**13.0**	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	*710.0*
	85/06/05	<5.0	ND	<5.0	<5.0	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	<100.00
A31	85/06/05	<5.0	ND	<5.0	*13.0*	<15.0	<10.0	NA	*320.0*	<50.0	320.0	<50.0	*2300.0*
	84/06/15	<5.0	2.1	<5.0	*17.0*	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	**12000.0**
A32	85/06/05	<5.0	ND	<5.0	6.6	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	*1500.0*
	85/06/05	<5.0	ND	<5.0	5.0	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	510.0
A34	88/07/28	<5.0	ND	<5.0	<5.0	<15.0	<10.0	NA	ND	<50.0	<50.0	<50.0	<100.00
A42	86/10/02	<5.0	ND	<5.0	6.3	<15.0	<10.0	NA	**676.0**	<50.0	**620.0**	56.0	<100.00

< = below indicated detection limit

Exceeds NAS Recommendations

Exceeds EDL 85

Exceeds EDL 95

TABLE 1

Established Guidelines and Standards for Chemical Toxicities

Chemical	NAS[a] Recommended Guideline for Freshwater Shellfish (wet weight)		FDA[b] Action Level for Freshwater & Marine Shellfish (wet weight)	
	µg/g (ppm)	ng/g (ppb)	µg/g (ppm)	ng/g (ppb)
Mercury	-	-	1.0[c]	1,000
Aldrin	-	-	0.3	300
Chlordane (total)	0.1	100	0.3	300
Dieldrin	-	-	0.3	300
DDT (total)	1.0	1,000	5.0	5,000
Endosulfan	0.1	100	-	-
Endrin	-	-	0.3	300
Heptachlor	-	-	0.3	300
Heptachlor epoxide	-	-	0.3	300
HCH (Lindane)	0.1	100	-	-
PCB (total)	0.5	500	2.0[d]	2,000
Toxaphene	-	-	5.0	5,000

[a] National Academy of Sciences-National Academy of Engineering. 1973. Water Quality Criteria (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] As methyl mercury

[d] A tolerance, rather than an action level, has been established for PCB's (21CFR, 109. May 29, 1984). An action level is revoked when a regulation establishes a tolerance for the same substance and use.

TABLE 2

Established Duidelines and Standards for Chemical Toxicities

Chemical	Median International Standards for Trace Elements[a] (wet weight) ppm		Maximum Tissue Residue Levels[b] (MTRLs) in Inland Surface Waters	
	Freshwater	Shellfish	ppb	ppm
Arsenic	1.5	1.4	200.0	0.2
Cadmium	0.3	1.0	0.64	
Chromium	1.0	1.0	-	-
Copper	20.0	20.0	-	-
Lead	2.0	2.0	-	
Mercury	0.5	0.5	1.0	0.001
Nickel	-	-	28.0	0.028
Selenium	2.0	0.3	-	-
Zinc	45.0	70.0	-	-
Aldrin			0.05	
Chlordane			1.1	0.0011
Dieldrin			0.65	
DDT (total)			32.0	0.032
Endosulfan (total)			250.0	0.25
Endrin			3,000.0	3.0
Heptachlor			1.8	0.0018
Heptachlor epoxide			0.8	0.0008
Hexachlorobenzene			6.0	0.006
a-HCH			0.5	0.0005
b-HCH			1.8	0.0018
g-HCH			2.5	0.0025
PAHs (total)			0.08	
PCB (total)			2.2	0.0022
Toxaphene			8.8	0.0088

[a] Based on: Nauen. C.C., Compilation of Legal Limits for Hazardous Substances in Fish and Fishery Products, Food and Agricultural Organization of the United Nations, 1983.

[b] MTRLs for each substance (except for aldrin, As, and Hg) are calculated by multiplying the "California Inland Surface Waters Plan" Human Health Water Quality Objectives (SWRCB 1993a) by Bioconcentration Factors (BCFs) taken from the USEPA 1980 Ambient Water Quality Criteria Documents.

TABLE 3

State Mussel Watch Program Elevated Data Levels for
Resident and Transplanted Freshwater Clams
(1977-1993 Data)

Chemical	Resident Freshwater Clams (FWC) (ppb, wet weight)		Transplanted Freshwater Clams (TFC) (ppb, wet weight)	
	EDL 85	EDL 95	EDL 85	EDL 95
Aldrin	ND	ND	0.7	1.5
Chlordane	4.5	10.6	35.1	79.0
Dieldrin	1.2	1.5	110.4	196.9
DDT (total)	26.9	290.0	911.0	2493.7
Endosulfan (total)	ND	18.1	74.6	294.4
Endrin	ND	ND	17.0	29.3
Heptachlor	ND	ND	ND	0.3
Heptachlor epoxide	ND	ND	0.6	2.6
Hexachlorobenzene	0.3	0.5	1.3	2.9
a-HCH	0.3	0.5	0.1	0.4
b-HCH	ND	ND	ND	ND
g-HCH	ND	0.4	0.6	ND
PCB (total)	14.3	65.2	78.0	151.6
Toxaphene	ND	ND	603.2	2374.4

ND = EDL lies below the detection limit.
IS = Insufficient number of samples to calculate EDL.

TABLE 4

Toxic Substance Monitoring Program
Elevated Data Levels (EDL)
(1978-1987 Data)

Chemical	EDL 85 (wet weight) Whole Fish	EDL 85 (wet weight) Fish Filet	EDL 95 (wet weight) Whole Fish	EDL 95 (wet weight) Fish Filet
Elements (ppm)				
Arsenic	0.40	0.20	0.79	0.36
Cadmium	0.10	<0.01	0.17	0.01
Chromium	0.17	<0.02	0.25	<0.02
Copper	3.39	0.64	3.96	0.69
Lead	0.39	<0.01	0.53	<0.10
Mercury	0.06	1.00	0.07	1.90
Nickel	0.17	<0.01	0.42	<0.10
Selenium	1.60	2.00	3.27	3.40
Zinc	38.90	24.00	40.60	33.20
Organics (ppb)				
Aldrin	<5.0	<5.0	<5.0	<5.0
Chlordane	193.0	47.9	280.5	119.5
Dieldrin	295.0	12.0	570.0	40.0
DDT (total)	4058.6	898.0	9030.6	2572.6
Endosulfan (total)	56.6		271.2	22.0
Endrin	26.6	<15.0	59.0	<15.0
Heptachlor	<5.0	<5.0	<5.0	<5.0
Heptachlor epoxide	9.7	<5.0	17.0	<5.0
Hexachlorobenzene	8.0	<2.0	16.8	6.4
a-HCH	<2.0	<2.0	2.1	<2.0
b-HCH	<10.0	<10.0	<10.0	<10.0
g-HCH	4.3	<2.0	10.2	3.8
PCB (total)	288.0	150.0	583.2	439.5
Pentachlorophenol	-	3.2	-	5.4
Toxaphene	1460.0	400.0	4320.0	1281.0

STATE MUSSEL WATCH PROGRAM
1987 - 1993
DATA REPORT

94-1WQ

Prepared by
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Division of Water Quality

Field and Laboratory Operations Conducted by the
Moss Landing Laboratory
California Department of Fish and Game

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

1. STATE MUSSEL WATCH PROGRAM
1987 - 1993

Introduction

The California State Mussel Watch Program (SMWP) was initiated in 1977 by the California State Water Resources Control Board (SWRCB). The SMWP was organized to provide a uniform statewide approach to the detection and evaluation of the occurrence of toxic substances in the waters of California's bays, harbors, and estuaries through the analysis of mussels and clams. The SMWP primarily targets areas with known or suspected impaired water quality and is not intended to give an overall water quality assessment. The California Department of Fish and Game (DFG) carries out the statewide SMWP for the SWRCB by collecting and analyzing samples. The SWRCB provides funding under an ongoing interagency agreement with the DFG. Sampling stations are selected primarily by the six coastal Regional Water Quality Control Boards (RWQCB) which are identified on the inside back cover.

The DFG reports annual sampling results to the SWRCB, which distributes the information to the coastal RWQCBs and to other federal, State, and local agencies through annual preliminary data reports. These preliminary data reports are also routinely transmitted to the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency, which has responsibility for evaluating pollutant levels based on human health concerns and issuing consumption health advisories if indicated. This report is the formal report presenting the results of the 1987-93 sampling and analysis programs.

Information collected in the SMWP is used by the SWRCB, RWQCB, and other agencies to identify waters impacted by toxic pollutants. Through the SWRCB's statewide Water Quality Assessment/Clean Water Strategy, SMWP results are used to help classify water bodies from good to impaired water quality relative to each other and ranked according to this classification and resource value. For example, water bodies that exceed human health criteria are considered more impaired than water bodies that only exceed environmental protection criteria. SMWP results are also used in the SWRCB's Bay Protection Program in helping identify "Toxic Hot Spots". Lastly, SMWP results are used in the normal regulatory activities of the RWQCBs and other State agencies such as the Department of Pesticide Regulation.

Summary

Appendix A shows area map locations for each station sampled from August 1987 through March 1993. Appendix B contains station location information such as latitude and longitude and county identification. From 1987 to 1993 a total of 863 samples from 315 stations were collected and analyzed (Appendix C) including 776 samples of California mussel (*Mytilus californiaus*), bay mussel (*Mytilus edulis*), and freshwater clam (*Corbicula fluminea*), and 87 sediment samples. Two archive samples of California mussels from Point Pinole and the Dumbarton Bridge at Channel Marker 14 collected in 1981 and 1982, respectively, were also analyzed in 1989 upon special request. Samples were analyzed for trace elements (metals), organic chemicals (pesticides and PCBs), polynuclear aromatic hydrocarbons (PAHs), and tributyltin (TBT). Transplanted California mussels made up 62% of the tissue samples followed by resident California mussels (24%), transplanted freshwater clams (11%), resident bay mussels (2%), and resident freshwater clams (1%). A complete station sampling history of the SMWP from 1978 to 1993 is provided in Appendix D. Recently, station names were reviewed and updated to more accurately describe the location of the sampling site. These changes are listed in Appendix E by old station name.

Wet weight sampling results were compared to the following criteria: U.S. Food and Drug Administration (FDA) criteria, Maximum Tissue Residue Levels (MTRLs), Median International Standards (MIS), the National Academy of Sciences (NAS) recommended guidelines for predator protection, and Elevated Data Levels (EDLs). A discussion of each criterion can be found in Section 3, Administrative and Comparative Criteria on Page 5. The MTRL is a new criterion developed from water quality objectives from 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). Only three samples collected from 1987 to 1993 exceeded FDA criteria (Appendix F). Two samples exceeded the FDA action level for dieldrin of 300 ppb. Transplanted California mussels collected in 1988 from the Lauritzen Canal/End contained 602 ppb dieldrin and freshwater clams from Salinas/Reclamation Canal 4 collected the same year contained 396 ppb. The FDA tolerance level for PCBs (2,000 ppb) was exceeded in only one sample. Transplanted California mussels from San Diego Bay/Harbor Island/East Basin/Storm Drain also collected in 1988 contained 2,738 ppb PCBs. A total of 500 tissue samples from 216 stations exceeded the MTRLs for ocean waters (Appendix G), enclosed bays and estuaries (Appendix H), and inland surface waters (Appendix I). The NAS guideline for DDT (1,000 ppb) was exceeded in five transplanted freshwater clam samples from four stations (Appendix F). Two samples collected in 1988 from Salinas/Reclamation Canal 4 and Revolon Slough contained 2,556 and 3,845 ppb, respectively. A sample from Revolon Slough again exceeded the NAS for DDT in 1989 with 2,507 ppb. More recently, a sample from Salinas River Lag 2 station in 1992 contained 1,068 ppb while a 1993 sample from Watsonville Slough/Bridge station contained 1,058 ppb. The MIS for trace elements were exceeded in 528 samples from 203 stations from 1987 to 1993 (Appendix J). Samples exceeding EDLs for trace elements and organic chemicals can be found in Appendices K and F.

Tabular summaries of all chemistry data are provided in Appendices L through P. Summaries of all trace element data are provided in Appendix L (wet weight) and Appendix M (dry weight). Summaries of all organic chemical data are provided in Appendix N (wet weight), Appendix O (dry weight), and Appendix P (lipid weight). A separate table containing PCP and TCP results is located in Appendix Q. PAH data summaries can be found in Appendix R (wet weight), Appendix S (dry weight), and Appendix T (lipid weight). From 1987 to 1990 samples were analyzed for a large number of PCB congeners. These data can be found in Appendix U and V (wet weight), Appendix W and X (dry weight), and Appendix Y and Z (lipid weight).

Appendix DD is an errata sheet containing corrected phenol data from 1984-85 and 1986-87.

2. FIELD AND LABORATORY OPERATIONS

The presence of many toxic substances in the State's waters is determined by analyzing tissues from aquatic organisms. Concentrations of these substances in water are often too low or transitory to be reliably detected through the more traditional methods of analysis of water samples. Also, many toxic substances are not water soluble, but can be found associated with sediment or organic matter. Aquatic organisms are sampled because they bioaccumulate and bioconcentrate toxic substances to levels which may be many hundreds of times the levels actually in the water. This concentration factor facilitates detection of toxic pollutants. Mussels and clams are excellent subjects for this purpose because they (1) are sessile, (2) are long-lived, (3) can be successfully transplanted to and maintained in areas where they do not naturally occur, and (4) reliably concentrate toxic pollutants from the water. The following is a general overall discussion of field and laboratory procedures. A detailed discussion is provided in Appendix AA.

Substances Measured

Samples are regularly analyzed for up to 14 trace elements (Table AA-1) and approximately 45 synthetic organic chemicals including pesticides and PCBs (Table AA-3). Arsenic, nickel, selenium, polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), and tetrachlorophenol (TCP), and tributyltin (TBT) are looked for on a request basis only. Not every sample is analyzed for all trace elements or organic chemicals. Each sample at each station is handled individually. The requesting agency, usually the RWQCBs, will specify the type of analysis for each sample.

Sample Size and Collection

Forty-five mussels or clams are composited and analyzed for organic chemicals. Three analytical replicates of 15 individuals each of mussels or clams are analyzed for trace elements (trace element results reported herein are mean values). Concentrations in bivalves of certain trace elements and organic chemicals can be directly correlated with several variables such as size of the animal, location of habitation within the tidal zone, and season of collection (Stephenson et al. 1987). In the SMWP, mussels of 55 to 65 mm in length are collected whenever possible in order to reduce size-related effects. Clams size is limited to 20 to 30 mm in length. In an attempt to minimize variability introduced by location of collection within the inter-tidal zone, mussels are collected from the highest point in the zone where adequate numbers occur.

Mussels and clams are transplanted where a suitable resident population does not exist and where sampling can be accomplished using scuba equipment. The mussel transplant system, consisting of a bottom anchored float buoy used in water up to 40 m depth, is shown in Appendix AA, Figure AA-1. Bags of freshwater clams are usually tied to plastic stakes placed off the bottom or are attached to submerged structures. A two month transplant period is adequate in most cases where pollutant uptake rates are expected to be high, but for trace elements in less contaminated environments a six month interval may be necessary for an adequate sample (Stephenson et al. 1980). A four to six month transplant interval is used for organic chemicals to be consistent with transplant periods for trace elements. Transplanted mussels (M. californianus) were collected from Trinidad Head for the Humboldt Bay survey, from Montana de Oro for the Diablo Canyon survey, and from Bodega Head for all other transplants. Transplanted freshwater clams (C. fluminea) were collected from Lake San Antonio up to mid-1990. Because drought conditions at Lake San Antonio prevented further collections, clams were obtained from the Rio Vista area (Solano County) from 1990 through mid-1992. Clams collected from the Rio Vista area were held in Aptos Creek until transplanted. In 1992-93 clams were collected from Lake Isabella.

Dry, Wet, and Lipid Weight Measurements

Metal data are presented in parts per million (ppm), while organic chemical data are presented in parts per billion (ppb). Tissue concentrations of trace elements and organic chemicals are measured on a dry weight basis to reduce data variability due to moisture content. Wet and lipid data are back calculated from dry weight measurements. Wet weight data are used to compare to wet weight or fresh weight criteria listed in this report (see Section 3, Administrative and Comparative Criteria). In addition, organic chemicals are expressed on a lipid weight basis. Lipid weight measurements offer several advantages. Because chlorinated hydrocarbons are much more soluble in lipids (fat tissues) than in water, they partition into lipid-rich tissues of aquatic organisms (Stout and Beezhold 1981). Animals with higher proportions of lipid in their tissue usually have had higher concentrations of chlorinated hydrocarbon pollutants (Phillips 1980). Factors such as season, water temperature, health of the organism, stress on the organism, and type of species can affect the lipid levels of samples collected for analysis and can, therefore, cause variability in results. Use of lipid weight measurements may reduce this source of variability, although disadvantages have also been noted (Phillips 1980). As a result, lipid weight values may represent a more realistic measure of environmental availability of chlorinated hydrocarbons than wet weight values. Wet weight measures, however, remain the preferred measure for most readers because all criteria for human health and for predator protection are based on wet weight measures. Also, wet weight measures better reflect the exposure of predators or humans to the actual concentration in fresh mussels or clams .

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.

TABLE 1

NAS Guidelines and FDA Action Levels for Toxic Chemicals in Shellfish
(wet weight)

Chemical	NAS[a] Recommended Guideline for Freshwater Shellfish μg/g (ppm)	NAS[a] Recommended Guideline for Freshwater Shellfish ng/g (ppb)	FDA[b] Action Level for Freshwater and Marine Shellfish μg/g (ppm)	FDA[b] Action Level for Freshwater and Marine Shellfish ng/g (ppb)
Mercury	-	-	1.0[c]	1,000
DDT (total)	1.0	1,000	-	-
PCB (total)	0.5	500	2.0[d]	2,000
aldrin	-	-	0.3	300
dieldrin	-	-	0.3	300
endrin	-	-	0.3	300
heptachlor	-	-	0.3	300
heptachlor epoxide	-	-	0.3	300

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 As methyl mercury.

d 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.

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.

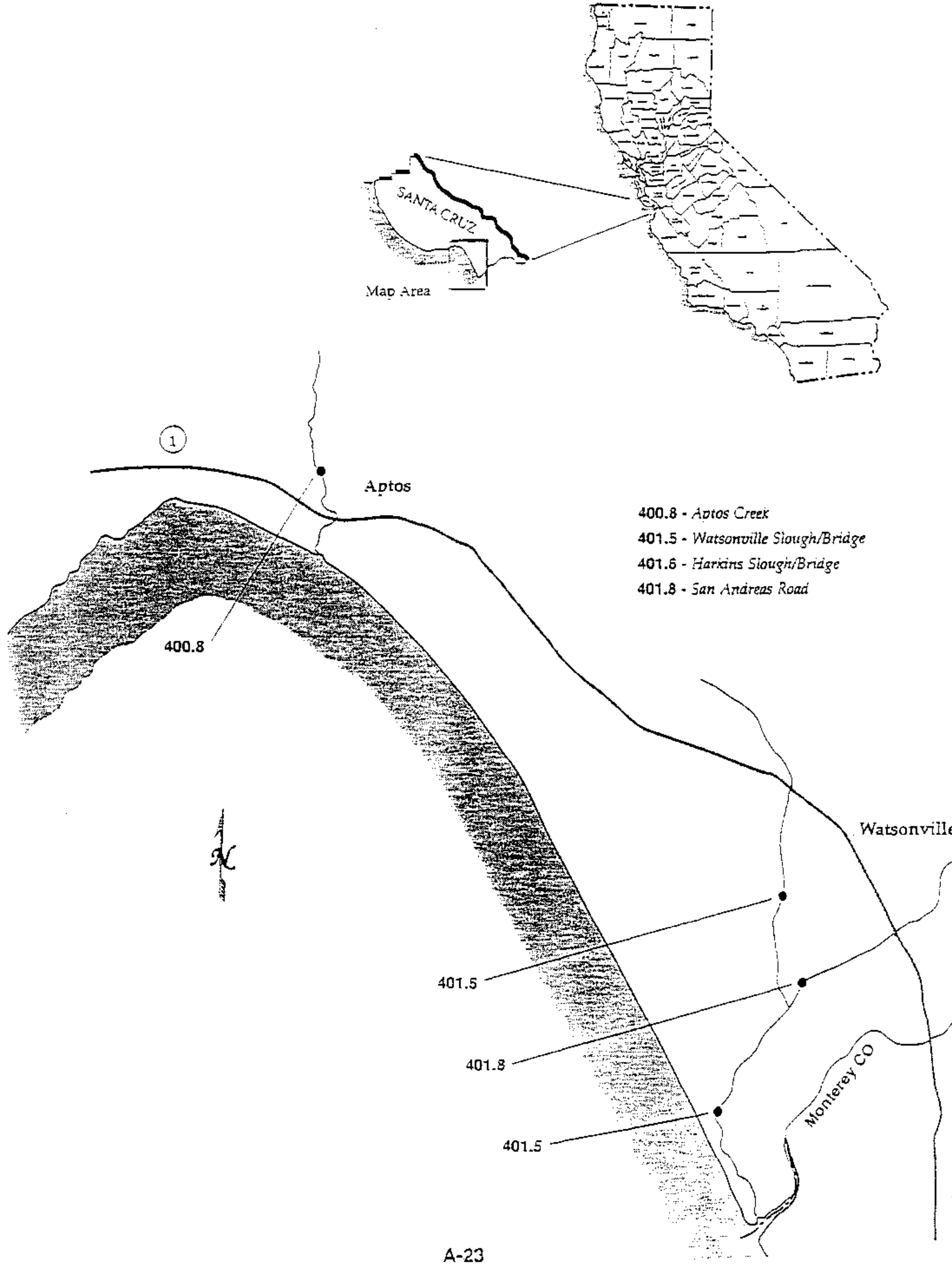
d. Aldrin MTRL is derived from a combination of aldrin and dieldrin risk factors and BCFs as recommended in the USEPA 1980 "*Ambient Water Quality Criteria for Aldrin/Dieldrin*" (USEPA 1980).

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).

STATE MUSSEL WATCH 1987-93 SAMPLING STATIONS

Santa Cruz Co. - Aptos Area



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	Chlorbenside	Total Chlordane	Chlorpyrifos	Dacthal	Diazinon	Total DDT	Dichlorobenzophenone
323.3	Palo Alto Outfall	TCM	02/09/90								
326.0	Palo Alto/Channel Marker 8	TCM	12/16/91								
326.0	Palo Alto/Channel Marker 8	TCM	02/01/93				1.4**				
399.7	San Lorenzo River/Felton	TFC	02/16/91								
401.1	Santa Cruz/T Dock	TCM	02/08/89								
401.3	Moss Landing/Yacht Harbor	TCM	01/04/89					6.4**			
401.5	Watsonville Slough/Bridge	TFC	02/02/88	1.0*					110.0**		4.0*
401.5	Watsonville Slough/Bridge	TFC	03/10/93	1.0*		49.4*				1058.1#	
401.6	Harkins Slough Bridge	TFC	02/02/88								6.2**
401.8	San Andreas Road	TFC	02/03/88	0.7*							

Station Number	Dicofol	Dieldrin	Total Endosulfan	Endrin	Ethion	alpha-HCH	beta-HCH	delta-HCH	Gamma-HCH	Heptachlor	Heptachlor epoxide	Hexachlorobenzene
323.3									0.8**		0.2*	
326.0									1.3**		0.2*	
326.0												
399.7										0.7**		
401.1												
401.3		14.2*	30.7*									
401.5	55.0*					0.1*				0.3**	3.0**	
401.5		170.0*		18.0*					0.7*		2.6**	
401.6	88.0*									0.3**	1.0*	
401.8	40.5*	126.0*									2.0*	

Station Number	Methoxychlor	Ethylparathion	Methylparathion	Oxadiazon	Phenol	Pentachlorophenol	Tetrachlorophenol	Total PCB	Tetradifon	Toxaphene	Tributyltin
323.3											
326.0				1.3*							
326.0											
399.7											
401.1											1560.0*
401.3											
401.5	2.40**										
401.5				28.0*						1500.0*	
401.6			1.8**								
401.8											

* 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 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	05/17/93				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

CALIFORNIA STATE MUSSEL WATCH
TEN YEAR DATA SUMMARY
1977 - 1987

WATER QUALITY MONITORING REPORT NO. 87-3

DIVISION OF WATER QUALITY

Prepared by:
Peter T. Phillips

MAY 1988
STATE WATER RESOURCES CONTROL BOARD

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	SO BAY E. COMM. BASIN	12/29/82	TCM					3792	
894.00	SO BAY E. COMM. BASIN	02/19/85	TCM					2412	
894.00	SO 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

TABLE 20 (CONTINUED)
MUSSEL WATCH ORGANICS RESULTS THAT EXCEED ELEVATED DATA LEVELS (EDLs)
DRY WEIGHT, PPB

STATION NUMBER	STATION NAME	SAMPLE TYPE	SAMPLE DATE	ALDRIN	CHLOR-BENSIDE	TOTAL CHLORDANE	CHLOR-PYRIFOS	DACTHAL	TOTAL DDT	O,P'-DDT	P,P'-DDT	DIAZINON
336.00	J. FITZGERALD	RCM	02/16/81									
400.00	ANO NUEVO	RCM	11/18/77						617.1			
400.00	ANO NUEVO	RCM	08/15/78						502.5			
400.00	ANO NUEVO	RCM	01/04/79						930.3*			
400.00	ANO NUEVO	RCM	10/17/82						541.9			
401.00	SANTA CRUZ HARBOR	TCM	05/29/80									
401.00	SANTA CRUZ HARBOR	TCM	11/24/80									
401.20	WATSONVILLE SLOUGH	TCM	11/17/82						1615.0	37.0	120.0	
401.20	WATSONVILLE SLOUGH	TCM	11/28/83		17.0*			830.0*	3244.0*	70.0*	540.0*	
401.20	WATSONVILLE SLOUGH	TCM	01/27/86					26.0		40.0	160.0	

STATION NUMBER	DIELDRIN	ENDRIN	TOTAL ENDO SULFAN	ENDO-SULFAN 1	HCH ALPHA	HCH BETA	HCH GAMMA	HCH DELTA	HEPTA-CHLOR	HEPTA-CHLOR EPOXIDE	HEXA-CHLORO-BENZENE	METHYL PARATHION
336.00					10.00	8.80	9.20*					
400.00												
400.00												
400.00												
400.00	13.0		14.0	14.0						1.40*		
401.00												17.0*
401.00			26.0	26.0	6.20	3.00*						
401.20			400.0	400.0								
401.20	240.0*	44.0*	3390.0*	1800.0*	6.60		6.30*			5.70*		
401.20	140.0	12.0	1370.0*	720.0*						2.70		

STATION NUMBER	METHOXY-CHLOR	TOTAL PCB	PCB 1248	PCB 1254	PCB 1260	PENTA-CHLORO-PHENOL	RONNEL	TETRA-CHLORO-PHENOL	TETRA-DIFON	TOXAPHENE
336.00										
400.00		330.0*		330.0*						
400.00		180.0		180.0						
400.00		370.0*		370.0*						
400.00		360.0*		360.0*						
401.00										
401.00										
401.20										950.0*
401.20										1300.0*
401.20										310.0

RCM = Resident California Mussel
TCM = Transplanted California Mussel

RBM = Resident Bay Mussel
FWC = Freshwater Clam

All Listed Values Exceed EDL 85
* = Exceeds EDL 95

TOXIC SUBSTANCES MONITORING PROGRAM

TEN YEAR SUMMARY REPORT

1978 - 1987

90-1WQ

Prepared by
Del Rasmussen and Heidi Blethrow
Division of Water Quality

WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA

EXECUTIVE SUMMARY

This report summarizes the results of the Toxic Substances Monitoring Program (TSMP) from 1978-1987. The TSMP was initiated in 1976 by the California State Water Resources Control Board (State Board) to provide a uniform statewide approach to the detection and evaluation of the occurrence of toxic substances in fresh and estuarine waters of the state. The California Department of Fish and Game (DFG) carries out the statewide TSMP for the State Board by collecting and analyzing fish and other aquatic organisms from selected sampling stations. The State Board provides funding for the program under an ongoing annual interagency agreement with the DFG. The intent of this report is to provide an overview of the program from 1978-1987 and to make it easier to find and use the TSMP results. This report does not replace the previously published annual TSMP reports which provide detailed assessments of results (SWRCB, 1979a through 1982a, 1983, 1985 through 1988a, and 1989).

Waterbodies sampled in the TSMP were selected because of suspected water quality problems. Thus, it is not surprising that most of these waterbodies exceeded at least one comparative criteria. Overall assessment of the data, however, indicates that many of the sampled waterbodies probably do not have significant bioaccumulation problems. The following waterbodies or areas consistently exceeded comparative criteria:

Metals

Region 1 - Fish and invertebrates from the north coast area contained elevated levels of chromium and nickel.

Region 2 - Fish collected from the Guadalupe River area and Lake Herman contained mercury levels exceeding FDA action levels to protect human health. The Department of Health Services (DHS) issued health advisories for both areas. Samples from Suisun Bay contained high levels of arsenic, copper, silver, and zinc.

Region 3 - The FDA action level for mercury was exceeded in fish from Lake Hernandez and Lake Nacimiento. The DHS issued a health advisory for Lake Nacimiento. Lake San Antonio contained some of the highest cadmium levels found in the State.

Region 4 - Fish from the San Gabriel River contained elevated levels of copper, lead, nickel, and silver.

Region 5 - Mercury levels exceeding FDA and NAS criteria were found in many areas of the Region including the American River, Beach Lake, Lake Berryessa, Clear Lake, Feather River, and Don Pedro Reservoir. Health advisories were issued by the DHS for Lake Berryessa and Clear Lake. Other metals were also detected at high concentrations in Region 5, particularly at the Keswick station on the Sacramento River.

Region 6 - Silver regularly exceed criteria in the East Walker and Truckee Rivers.

Region 7 - The TSMP uncovered a widespread selenium pollution problem in the Region. High selenium levels were found in the Salton Sea area and in the Colorado River. A health advisory was issued by the DHS for the Salton Sea.

Region 8 - Elevated metal levels were found at a number of stations on San Diego Creek

Region 9 - The Tijuana Estuary consistently exceeded metal criteria in samples collected from 1984 to 1987.

Organic Chemicals

The most frequently detected pesticides were chlordane, dacthal, DDT, dieldrin, and toxaphene. DDT residues were found in most samples analyzed indicating that DDT accumulation is still a problem in California. Areas where pesticide and PCB levels were found in high concentrations over many years include:

Region 3 - The Salinas and Watsonville areas. Fish from Blanco Drain exceeded FDA action levels for DDT and dieldrin.

Region 4 - Calleguas Creek, Harbor Park Lake, and Revolon Slough. The FDA action level for chlordane was exceeded in Harbor Park Lake and Puddingstone Reservoir. The DHS issued a health advisory for Harbor Park Lake because of high chlordane and DDT levels found by the TSMP.

Region 5 - The Merced, Sacramento, San Joaquin, Stanislaus, and Tuolumne River drainages. FDA action levels were exceeded in fish from the Feather River (PCBs), Paradise Cut (chlordane and DDT), and the San Joaquin River (chlordane, DDT, and toxaphene). The Vernalis station on the San Joaquin River had the most FDA exceedances with six occurring in 1983, 1984, and 1986.

Region 7 - The Alamo and New River drainages. Fish from the Alamo River exceeded the FDA action level for DDT.

Region 8 - San Diego Creek.

Region 9 - Fish from the San Diego River exceeded the FDA action level for chlordane.

Chapter 1

PROGRAM EVOLUTION

From 1978 to 1987, the TSMP sampled 303 stations from over 200 waterbodies statewide. Appendices A through C provide sampling station information. Sampling history for each station is provided in Appendix D. More than 1,200 samples representing 69 species were analyzed over the ten year period (Appendix E). A total of 61 fish species, six invertebrate species, one turtle, and a plankton sample were collected (Table 1). Largemouth bass, carp, and channel catfish were the most frequently collected species (Table 2). These three species made up approximately 40% of all samples. The Program averaged 120 samples and 56 stations monitored per year from 1978 through 1987. There was, however, a significant increase in workload in the Program starting in 1983. From 1978 to 1982, the TSMP averaged 77 samples from 40 stations per year. The average annual workload increased to 163 samples from 73 stations for the period 1983 to 1987. The largest number of samples (250) was collected in 1986, while the most stations monitored in any one year occurred in 1987 when samples were obtained at 93 stations. The following is a year by year discussion of the historical evolution of the TSMP:

1976-77: Developmental period for the TSMP. Modifications and improvements were made in both sampling and analytical techniques. Data collected during this time are not compared with following years data because of different methods and tissues used. The "Primary Water Quality Monitoring Network" (Primary Network) was established during this period. The Primary Network was made up of sampling stations on 28 high priority streams identified for the State Board by the Department of Water Resources (DWR, 1976). Primary Network stations were located in all Regions, except Region 4. The purpose of the Network was to provide an overall continuing assessment of water quality in the state. Initial program objectives included development of baseline data to: (1) document trends, (2) assess impacts of accumulated toxicants, and (3) attempt to identify sources of pollutants. These objectives were later modified to meet Regional Board needs. Measuring pollutant levels in resident aquatic organisms was selected as the method of choice. Nine metals or trace elements and 64 synthetic organic compounds were chosen for analysis. Benthic invertebrates, forage and predator fish, and sediment were analyzed at each station. Sediment sampling was soon dropped during this time period because of unsatisfactory results. Sampling was conducted during fall (low flow) and spring (high flow). Results led to a recommendation to perform sampling only at low flows during summer and fall. Data were compared to FDA and NAS criteria. The overall result during this time period was the formalizing of the basic TSMP.

1978: First full sampling year using standardized procedures and techniques. Forage and predator fish and invertebrates were analyzed from 26 stations. All but one of the stations were part of the Primary Network. No stations in Region 9 were sampled in 1978. A total of 70 samples from 26 waterbodies were analyzed for nine metals and 70 organic substances. Fish samples were standardized, whenever possible, to include a composite of six individual, medium sized, young adults. Large numbers of more normal sized fish were thought to provide better estimates of mean concentrations of toxicants. Mercury and organic substances were analyzed in fish flesh to compare data to human consumption criteria (FDA action levels). Metals were analyzed in fish livers for best comparative results. Water samples* were collected at most stations analyzed for pesticides. Generally, compounds found in water samples were not detected in tissue samples. Likewise, compounds measured in tissue samples were rarely detected in water samples. Action plans were formulated for waterbodies with specific bioaccumulation problems. Eight waterbodies were identified as warranting immediate follow-up action. Recommendations were made to expand the program by sampling additional waterbodies.

1979: Samples were analyzed from 28 stations, all but one from the Primary Network. Fifty-four samples from the 28 waterbodies were analyzed for nine metals and 56 organic substances. Both benthic invertebrates and fish continued to be collected. The number of species increased, due primarily to the lack of appropriate species at a number of stations. The difficulty in obtaining the desired species from station to station and year-to-year will continue to plague the program. Field replicates were introduced in 1979 along with interlaboratory comparison. Special "action plan" sampling was carried out on the eight waterbodies recommended for such sampling in 1978.

1980: Fish and invertebrates were analyzed from 66 stations (45 waterbodies). Twenty-five stations were part of the Primary Network. All but one of the remaining 41 stations were sampled for the first time in 1980. Samples were not collected in Region 2. A total of 121 samples were analyzed for nine metals and 56 organic substances. Intensive sampling (action plan sampling) was conducted on the Feather River (Region 5) for PCBs and the San Joaquin River (Region 5) for pesticides. Action plan sampling continued on previously recommended waterbodies. An absorbent water column sampler* was used on the San Joaquin and Feather Rivers. Less frequent sampling of Primary Network stations was proposed. The large number of new stations sampled in 1980 indicated a shift in objectives from long term assessment monitoring at fixed stations to more of a "hot spot" monitoring program (see Long Term Monitoring Chapter). This shift was also done to expand the statewide data base.

1981: Fish were analyzed from 43 stations (39 waterbodies). Sixteen stations were sampled for the first time and 20 stations were from the Primary Network. Region 4 was sampled for the first time, while Region 9 was not sampled in 1981. A total of 61 samples were analyzed for 10 metals and 66 organic substances. Selenium was added to the chemical scan and was monitored at one station in Region 5. Water column sampling* was conducted on the Salinas River (Region 3) and Colusa Drain (Region 5). Routine benthic invertebrate sampling was discontinued in 1981. It was felt at the time that the limited TSMP budget could be better spent concentrating on fish tissue analysis rather than sampling both fish and invertebrates.

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* Water and sediment data collected from 1978 through 1982 are not included in this report because of differences in sampling and laboratory techniques. This information can be found in the appropriate annual TSMP report or in the 1984 summary report.

Stations were assigned a seven digit hydrologic unit number code that specifies station location within each Region. The 1981 TSMP report introduced regional discussion of results. All data from 1978-81 were included in this report. A precursor to EDLs was used to evaluate all the data. Mean values and standard deviations were calculated and compared.

1982: A total of 79 samples from 37 stations (34 waterbodies) were analyzed for 9 metals and 71 organic substances. Eleven Primary Network stations were sampled. Sixteen stations were sampled for the first time. Yearly sampling of most Primary Network stations was dropped in favor of an expanded statewide monitoring program. Water and sediment sampling* were conducted at selected sites. Intensive surveys for mercury were conducted in Clear Lake (Region 5), Lake Nacimiento (Region 3), and the American River (Region 5). Samples archived in 1980 were analyzed for metals. TSMP data was entered into a main frame computer system for improved storage and analysis. A recommendation was made to drop absorbent water column sampling because it was not cost effective.

1983: A total of 186 fish samples were analyzed from 50 stations (42 waterbodies). Nineteen stations were sampled for the first time. Samples were monitored for 10 metals and 61 organic substances. Selenium was again monitored at one station. Intensive surveys were conducted in Clear Lake and Lake Nacimiento for mercury, Los Angeles recreational lakes (Region 4) for metals and pesticides, and the New and Alamo Rivers (Region 7) for pesticides. EDLs (called "Elevated Toxic Pollutant Levels" in the 1983 report) and Median International Standards (MIS) were introduced as comparative criteria in 1983. A recommendation was made to employ lipid weights as a basis for data comparison.

1984: Samples were analyzed from 74 stations (60 waterbodies). One archived sample collected in 1984 was analyzed and reported in 1985. Thirty-eight stations were sampled for the first time. One hundred-six fish samples and 11 sediment samples were analyzed for 10 metals and 65 organic substances. Routine analysis of selenium in fish livers was introduced. The 1984 TSMP report summarized all data collected since 1978. Included in the summary was lipid weight data back to 1980. Lipid weight values prior to 1980 were not considered reliable due to equipment changes. The sum of a number of pesticides, called Chemical Group A, was first used to evaluate data. A DHS health advisory level for mercury was introduced as a comparative criteria. This advisory level was dropped in 1986. Data storage and analysis was switched to a personal computer (PC) for easier access. Water and sediment data collected before 1984 and reported in the summary section of the 1984 report were not included in the TSMP PC data base. Differences in sampling and laboratory techniques were the main reasons for not including these data.

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* Water and sediment data collected from 1978 through 1982 are not included in this report because of differences in sampling and laboratory techniques. This information can be found in the appropriate annual TSMP report or in the 1984 summary report.

1985: Forty-six of the 72 stations (57 waterbodies) sampled in 1985 were monitored for the first time Data from six of these stations were included in the 1986 report. One 1984 archived sample was included in the 1985 report. A total of 138 fish samples and one sediment sample were monitored for the now routine scan of 10 metals and 45 organic substances. A number of pesticides were dropped from routine analysis because they had never been detected and because of budget constraints. Selenium analysis was switched from livers to filet on a routine basis in order to compare data to a new DHS health advisory level for selenium. Intensive monitoring for pesticides was conducted in the Monterey area (Region 3) and tributaries to the New River (Region 7). A mercury survey was also conducted in Lake Berryessa (Region 5).

1986: The largest number of samples (250) yet analyzed were collected from 76 stations (72 waterbodies). Six clam samples collected in 1985 were also analyzed and reported in 1986. Fifty-three stations were sampled for the first time. A routine analytical scan was performed on all samples. Intensive surveys for mercury were conducted in the Guadalupe River area (Region 2), and Lake Herman (Region 2). In addition, a number of stations in Region 7 were surveyed for selenium. All station names were standardized. The DHS health advisory levels for mercury and selenium were dropped as comparative criteria at the request of DHS staff. DHS criteria were replaced with MIS. Starting in 1986, the usual two samples per station was discontinued and only one sample per station would be routinely collected. This change was made for budgetary reasons.

1987: Samples were analyzed from 93 stations (77 waterbodies), the most yet sampled in the TSMP A total of 137 samples were analyzed. Fifty-one of the stations were sampled for the first time. Fish were collected at 85 of the stations. At the remaining eight stations, transplanted freshwater clams were analyzed at four stations in Region 1, soil samples were analyzed at three stations in Region 3, and a spiny soft shell turtle was analyzed at one station in Region 7. Plankton were also analyzed, in addition to fish, at the Salton Sea in Region 7. Nine stations were part of an Orange County (Region 8) urban lakes survey, while two marine stations, Monterey Harbor and Moss Landing Harbor (Region 3), were also sampled. Nearly 100 sampling station numbers were revised to reflect revisions to the State Board's basin planning maps.

Chapter 2

FIELD AND LABORATORY OPERATIONS

The presence of toxic substances in fresh waters is determined by analyzing tissues from fish and other aquatic organisms. Concentrations of these substances in water are often too low or transitory to be reliably detected through more traditional methods of analysis of water samples. Also, many toxic substances are not water soluble, but can be found associated with sediment or organic matter. Fish and other aquatic organisms are sampled because they bioaccumulate and bioconcentrate toxic substances to levels which may be many hundreds of times the levels actually in the water. This concentration factor facilitates detection of toxic pollutants. In interpreting the TSMP 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 (see Long Term Monitoring Chapter). 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 in a particular species provide only an indication of areas where fish are evidently accumulating concentrations which are above "normal". The following is a general overall discussion of field and laboratory procedures. A review of field and laboratory procedures is provided in Appendix F.

Substances Measured

A total of 10 metals or trace elements and 45 pesticides and PCBs (organic chemicals) are analyzed in the TSMP on a regular basis. Additional substances, such as pentachlorophenol (PCP) and tetrachlorophenol (TCP), are looked for on a request basis only. Not every sample is analyzed for all metals or organic chemicals. Each sample at each station is handled individually. The requesting agency, usually the Regional Boards, will specify the type of analysis for each sample. All metals, except mercury and selenium, are routinely analyzed in liver tissue. Mercury, selenium, and all organic chemicals are analyzed in muscle tissue (filet). When only very small fish are available, metal or organic chemical analysis is performed on a whole-body composite of larger than usual numbers of individual fish.

Sample Size

Composite samples, using six fish of each species, are collected whenever possible. The number and size uniformity of the fish in each composite depends upon their availability. Replicate composites are collected and analyzed to measure the variability of toxicant concentrations in single species composites collected at the same time and place. Collection of the same species from all stations is desirable to minimize possible variation in the data due to differences in pollutant uptake between species. However, this is not possible over the entire State due to the variety of habitat sampled in the program. All reasonable efforts are made to maintain both station-to-station and year-to-year uniformity in collections. In general, predator fish are desired from all stations. Forage fish are desired as supplemental samples at stations where pollution problems are known to exist, or as substitute samples where predatory fish are not available.

Wet and Lipid Weight Measurements

Tissue concentrations of metals and organic chemicals are measured on a wet weight basis. Metal data are presented in parts per million (ppm), while organic chemical data are presented in parts per billion (ppb). Plankton and soil samples are analyzed on a dry weight basis. In addition to wet weight measures, organic chemicals are also expressed on a lipid weight basis. Lipid weight measurements offer several advantages. Because chlorinated hydrocarbons are much more soluble in lipids (fat tissues) than in water, they partition into lipid-rich tissues of aquatic organisms (Stout and Beezhold, 1981). Animals with higher proportions of lipid in their tissue usually have had higher concentrations of chlorinated hydrocarbon pollutants (Phillips, 1980). Factors such as season, water temperature, health of the organism, stress on the organism, and type of species can affect the lipid levels of samples collected for analysis and can, therefore, cause variability in results. Use of lipid weight measurements may reduce this source of variability, although disadvantages have also been noted (Phillips, 1980). As a result, lipid weight values may represent a more realistic measure of environmental availability of chlorinated hydrocarbons than wet weight values. Wet weight measures, however, remain the preferred measure for most readers because all standards for human health and for predator protection are based on wet weight measures. Also, wet weight measures better reflect the exposure of predators or humans to the actual concentration in freshly caught fish.

Station Numbers

Each TSMP station is identified by a unique seven digit number derived from the State Board's hydrologic basin planning maps. The first digit of a station number signifies one of the nine Regional Boards. The second and third digits represent a hydrologic area, while the fourth and fifth digits identify a hydrologic subarea. The sixth and seventh digits represent the distance in miles above the downstream hydrologic boundary. For example, station 519.21.01 is in Region 5, hydrologic area 19, subarea 21, and is one mile upstream from the hydrologic unit boundary. Not all mileage indicators are accurate, however. In certain instances, it was necessary to assign an arbitrary mileage indicator designated by numbers running from 90 to 99. For example, the arbitrary designation is used when two or more stations within the same hydrologic subarea are located within the same number of miles of the hydrologic boundary, resulting in the same station number. In this case, one or more of the stations is arbitrarily assigned a mileage designator from 90 to 99. In 1986, station names were revised to more accurately reflect station location. Station name changes are listed in Appendix G. In 1987, basin planning maps were updated resulting in hydrologic unit boundary changes. Appendix H lists station number changes resulting from redrawn boundary lines.

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

TABLE 3

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

Chemical	NAS[a] Recommended Guideline (Whole Fish) ug/g (ppm)	ng/g (ppb)	FDA[b] Action Level (Edible Portion) 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.

TABLE 4

Median International Standards for Trace Elements
in Freshwater Fish and Marine Shellfish [a]
(edible portion, ppm, wet weight)

Element	Fish	Shellfish	Range	Number of Countries with Standards
Antimony	1.0	1.0	1.0 to 1.5	3
Arsenic	1.5	1.4	0.1 to 5.0	11
Cadmium	0.3	1.0	0.05 to 2.0	10
Chromium	1.0	1.0	1.0	1
Copper	20.0	20.0	10 to 100	8
Fluoride	150.0	-	150.0	1
Fluorine	17.5	-	10 to 25	2
Lead	2.0	2.0	0.5 to 10.0	19
Mercury	0.5	0.5	0.1 to 1.0	28
Selenium	2.0	0.3	0.3 to 2.0	3
Tin	150.0	190.0	50 to 250	8
Zinc	45.0	70.0	40 to 100	6

a Based on: Nauen, C. C., Compilation of Legal Limits for Hazardous Substances in Fish and Fishery Products, Food and Agriculture Organization of the United Nations, 1983.

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.

Chapter 6

CHEMICAL OVERVIEW

This chapter presents a general overview of results for each chemical detected by the TSMP from 1978 to 1987. Stations where organic chemicals or metals exceeded criteria are presented by Region in the Regional Overview Chapter in Tables 11-28. References to chlordane, DDT, endosulfan, HCH, and PCB concentrations are to be considered total concentrations unless otherwise specified.

Synthetic Organic Chemicals

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 (SWRCB, 1988c). Subsequently, all uses on food crops were banned in 1985. In 1988, aldrin was no longer registered in California (SWRCB, 1988c). Aldrin is a known carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Statewide use of aldrin increased gradually from 1978 (530 lbs.) to 1984 (18,835 pounds). A dramatic increase in use occurred in 1985 when 148,335 pounds were applied, after which aldrin usage dropped to 12,469 pounds in 1986 and 2,481 pounds in 1987 (DFA, 1980 through 1989). Aldrin was primarily used over the years for structural pest control (yearly average 95%) and residential pest control. Statewide, aldrin was detected in less than 1% of the samples (a total of 5 samples). Aldrin was detected in Regions 5, 7, and 8. The highest levels were found in Region 5. The highest value (133 ppb) occurred in a 1978 clam sample from the Sacramento River (Region 5). The next highest value was 15 ppb in catfish from Colusa Drain (Region 5) in 1985.

Chlorbenside

In 1983, the TSMP mistakenly reported the presence of chlorbenside in samples from the Old Salinas River (Region 3) and San Diego Creek (Region 8). Later review of the data indicated that these samples most likely did not contain detectable levels of chlorbenside. No other samples have had detectable levels of this chemical.

Chlordane

Chlordane is a mixture of chlorinated hydrocarbons used alone or in combination with heptachlor for subterranean termite control. Prior to December 1987, existing stocks of all chlordane and heptachlor termiticides could be applied consistent with label instructions (SWRCB, 1988c). From December 1987 to April 1988, these termiticides could be applied only by certified operators. 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 statewide application of chlordane as a pesticide fluctuated between 1978 and 1981, with an average of 231,906 pounds per year (DFA, 1980 through 1983). Registered levels of chlordane reached the lowest usage of 105,795 pounds in 1982 and subsequently increased over the next five years to a peak of 639,529 pounds in 1987 (DFA, 1984 through 1989). The primary purpose for application of chlordane in California was for structural pest control. The amount used for this purpose increased from 79% of the total usage in 1978 to 99% in 1987. Other uses for chlordane included residential pest control, landscape maintenance, and a small percentage for agricultural crops.

Total chlordane was detected in 45% of the samples collected from 1978 to 1987. The two most predominant chlordane isomers found were trans-nonachlor and cis-chlordane. Chlordane values exceeded FDA action levels 5 times in Region 4, 3 times in Region 5, and once in Region 9. Samples from Regions 2, 3, 4, 5, 7, and 8 exceeded the NAS guideline for chlordane. Although still high in 1987, overall chlordane concentrations have decreased statewide since 1983. The highest chlordane levels found statewide occurred in three goldfish samples from Harbor Park Lake in 1983 and 1984 (1,890, 2,215, and 2,399 ppb). The highest rate of detection (85%) as well as the most exceedances of both FDA and NAS criteria were found in Region 4, primarily in the Harbor Park Lake area. The highest values found in tissues on a lipid weight basis (23,305 ppb) were also from Harbor Park Lake. Other areas exhibiting high frequencies of detection as well as exceeding FDA and NAS limits include: San Leandro Creek in Region 2; the Watsonville- Salinas Valley area in Region 3; the central San Joaquin Valley (Sacramento, Stanislaus, Tuolumne, Merced and San Joaquin Rivers) in Region 5; south Salton Sea area (Rice Drain 3, Alamo and New Rivers) in Region 7; and San Diego Creek in Region 8.

Chlorpyrifos

Chlorpyrifos, an insecticide sold as Dursban, Lorsban, and Stipend, had extensive home and agricultural use. Dursban is applied for the control of household insects such as ants, cockroaches, termites, and ornamental plant insects as well as for the control of cattle flies. Lorsban is both a soil and foliar insecticide applied to corn, alfalfa, fruit trees, nuts, and other vegetable crops. Stipend is used primarily on mushrooms for fly control (FCH, 1987). Other reported uses include control of mosquitos in wetlands and turf-destroying insects on golf courses (Odenkirchen and Eisler, 1988). At present there are no California or EPA use restrictions for chlorpyrifos (SWRCB, 1988c). The EPA considers chlorpyrifos extremely toxic to fish, birds, and other wildlife (USEPA, 1986b).

The statewide use of chlorpyrifos has increased over the years. Usage in 1987 (1,064,979 lbs.) was over 19 times that of 1978 (55,210 lbs). Peak use occurred in 1984 with 1,070,312 pounds applied primarily on cotton and alfalfa. Other uses of chlorpyrifos include fruit trees, other vegetable crops, and structural pest control (DFA, 1980 through 1989). Chlorpyrifos was by far the most widely used of the pesticides monitored in the TSMP since 1984.

Chlorpyrifos was detected in every Regions, except Regions 2 and 6. The TSMP found chlorpyrifos in 8% of the samples from 1978 to 1987. Several areas exhibited increased rates of detection in 1986 and 1987, accompanied by levels exceeding criteria. A majority of the chlorpyrifos values (wet and lipid weight) exceeding criteria have occurred in Region 7, especially in the south Salton Sea area. From 1985 to 1987, levels of chlorpyrifos exceeded all prior years in this area of Region 7. The highest statewide concentrations were 1,200 ppb in Rice Drain 3 in 1985 and 420 ppb in the Alamo River in 1987, both Region 7 stations. There appears to be evidence of increasing levels of chlorpyrifos in the Salton Sea area, especially at the Alamo River/Calipatria station. Other region-wide highs for wet and lipid weight values were recorded in lower Salinas Valley (Region 3), Harbor Park Lake (Region 4), lower Yuba River and Paradise Cut (Region 5), Santa Ana River (Region 8), and San Marcos Creek (Region 9).

Dacthal

Dacthal or chlorthal-dimethyl is a pre-emergence herbicide for the control of broadleaf weeds and grasses. It has been used on turf, ornamentals, and various crops such as soybeans, beans, cotton, garlic, cole crops, onions, broccoli, radishes, potatoes, and melons (DFA, 1980 through 1989). Dacthal is an aromatic carboxylic acid. Its herbicidal activity is inhibition of cell division. Application of dacthal doubled from 495,626 pounds in 1978 to a peak use of 1,304,193 pounds in 1980, followed by a marked decrease in subsequent years to a low of 266,854 pounds in 1982 (DFA, 1980 through 1984). From 1983 to 1987 usage leveled off to an average yearly application of 410,570 pounds (DFA, 1985 through 1989). The majority of dacthal was applied to onion and broccoli crops.

Dacthal, detected in 22% of the samples, was found in every Region, except Regions 6 and 9. From 1978 to 1981, the frequency of dacthal detection in fish tissue samples statewide increased from 6% to 18% and then, in 1982, increased to 33%. From 1982 to 1987, the detection rate for dacthal remained relatively constant at about 29%. Dacthal criteria were exceeded in Alameda Creek (Region 2), Salinas Valley (Region 3), Oxnard area and Harbor Park Lake (Region 4), Sacramento River and Colusa Drain (Region 5), Salton Sea area (Region 7), and San Diego Creek (Region 8). High levels of dacthal on both wet and lipid weight bases were consistently found in Region 7. The highest wet weight concentration (5,700 ppb) was found in carp from Rice Drain 3 (Region 7) in 1985. The highest lipid weight value (164,179 ppb) was detected in channel catfish at Coachella Valley Stormwater Channel in 1987, indicating that fish continued to be exposed to high levels of dacthal in Region 7.

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 (USEPA, 1986c). 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 (USEPA, 1986c).

The EPA is requiring the reduction of DDT and related impurities in dicofol to less than 0.1% by 1989 (USEPA, 1986c). 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.

DDT was detected in 84% of the samples from all regions from 1978 to 1987. The average level of p,p' DDE in fish filet samples (415 ppb) was on a par with the nationwide average. A higher average p,p' DDE level occurred in whole fish samples (1,240 ppb). The whole fish average exceeded the NAS guidelines of 1,000 ppb for total DDT. In general, levels of DDT and its metabolites in fish have not shown a decline with the cancellation of use of DDT. Levels of DDT above FDA and NAS criteria were found in Regions 3, 4, 5, 7, 8, and 9. Six samples from Regions 3, 5, and 7 exceeded the FDA action level of 5,000 ppb. The highest DDT concentration (17,558 ppb) occurred in Sacramento squawfish from Blanco Drain (Region 3) in 1985. The highest lipid weight values (1 to 2 parts per thousand) were detected in goldfish from Calleguas Creek (Region 4) in 1985 and 1986. Areas where high levels of DDT were found include: the lower Salinas Valley and Watsonville area in Region 3; Revolon Slough, Calleguas Creek, and Harbor Park Lake (Region 4); the San Joaquin and Sacramento Rivers (Region 5); the Alamo and New Rivers (Region 7); San Diego Creek (Region 8); and the Tijuana Estuary (Region 9).

Diazinon

Diazinon, an organophosphate insecticide and nematocide, is used extensively for control of household insects, soil insects, and pests of edible crops and other plants (FCH, 1987). Diazinon use averaged 500,000 pounds from 1978 to 1987, with the highest usage of 709,000 pounds occurring in 1987 (DFA, 1980 through 1989). The primary reported use up to 1983 was for alfalfa. In 1983, the major use changed to structural pest control.

Diazinon was rarely detected in the TSMP. Only two samples out of over 600 analyzed contained detectable levels. Both samples were collected in 1983. One sample was collected from Carpinteria Marsh and contained 92 ppb in a whole sample of longjaw mudsuckers. The other sample was collected from Harbor Park Lake (Region 4) and contained 60 ppb in a filet sample of goldfish.

Dicofol and Dichlorobenzophenone (DBP)

Dicofol, or kelthane, is an organochlorine miticide applied to fruit, vegetable, ornamental, and field crops. Of the average yearly use of 509,315 pounds (1978-1987), about half was applied to cotton. Dicofol was also applied to numerous agricultural commodities, including oranges, melons, corn, beans, and watermelons. Statewide use of Dicofol has gradually decreased each year from 1,004,828 pounds in 1978 to 259,626 pounds in 1987 (DFA, 1980 through 1989). In 1984, the EPA reviewed the registration of dicofol because of potential adverse effects on nontarget wildlife from DDT and related impurities of dicofol. A secondary concern was the impact of dicofol itself on avian reproduction. After review of the environmental risk posed by dicofol, the EPA required the reduction of DDT and related impurities in dicofol to less than 0.1% by 1989. Until 1989, registrants may sell and distribute dicofol containing 2.5% or less of DDT and related impurities (USEPA, 1986c).

Dicofol and DBP, one of its breakdown products, were rarely detected in TSMP samples. Initially found in 1984 and once in 1986, no other samples contained either compound. Dicofol was detected in six out of the 687 samples. All six samples were from Regions 5 and 7. DBP was detected in only four out of those six samples. Dicofol was found in the Sutter Bypass, Tuolumne River, Stanislaus River, and San Joaquin River in Region 5. Dicofol was also detected in the New River in Region 7. The highest concentration of dicofol was 480 ppb was detected twice in the San Joaquin River in 1984 and 1986.

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 (SWRCB, 1988c). Dieldrin is a known carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Dieldrin was detected in all Regions. Thirty-one percent of the samples statewide contained dieldrin levels above the detection limits. Regions 3 and 7 had the most samples with detectable levels (61% and 50%, respectively) in addition to most of the NAS exceedances for dieldrin. The Watsonville Slough and Salinas areas in Region 3 had especially high levels of dieldrin. In these two areas, dieldrin was detected in over 80% of the samples and close to 50% of these samples contained levels exceeding criteria. The three highest concentrations of dieldrin were found in whole fish samples from Watsonville Slough in 1984 (1,700 ppb) and in 1985 (960 and 810 ppb). The only sample to exceed the FDA action level was collected in Blanco Drain (Region 3) in 1985 and contained 550 ppb dieldrin.
The highest lipid weight values were also found in Region 3. In Region 7, two stations exceeded the NAS guideline: Rice Drain 3 (150 ppb) and Alamo River (110 ppb). The only sample to exceed the NAS guideline outside of Region 3 and 7 was one sample from Revolon Slough (120 ppb) in Region 4, collected in 1987.

Endosulfan

Endosulfan is a broad-spectrum insecticidal chlorohydrocarbon applied primarily to grapes, artichokes, alfalfa, tomatoes, melons, and head lettuce in California. The application of endosulfan increased gradually over the ten years, from 285,494 pounds in 1978 to 445,316 pounds in 1987 (DFA, 1980 through 1989). Average use was 355,636 pounds. In 1973, the DFA restricted the use of endosulfan in California. Subsequent restrictions have been adopted following the State Board's water quality assessment report recommendations. Endosulfan is extremely toxic to aquatic organisms, adversely affecting growth and development in the parts-per-trillion range (SWRCB, 1984a). Endosulfan is also acutely toxic to mammals. Endosulfan sulfate, the persistent breakdown product, is more toxic than the parent compound.

Total endosulfan has been detected in 14% of the samples statewide in Regions 3, 4, 5, 7, and 8. Samples from all these regions exceeded the NAS guideline. The pesticide is applied mainly in the Central Valley, the Monterey area, and Imperial County (SWRCB, 1984b). Monterey County has consistently used the greatest amount of endosulfan in the state with the majority of application along the Salinas River (SWRCB, 1984b). Endosulfan was detected in 80% of all samples from the Salinas area. Five of the six samples that exceeded the NAS guideline from this area were collected from 1985 to 1987. The highest concentration found (841 ppb) came from the Old Salinas River (Region 3) in 1983 In the Imperial Valley in Region 7, 71% of the samples contained detectable levels of endosulfan. In this area, six samples exceeded the NAS guideline. All but one of these six samples were collected from 1985 to 1987. Endosulfan is applied in Imperial County mainly for the control of pests on winter lettuce (SWRCB, 1984b). Other areas where endosulfan was found in high concentrations include: Revolon Slough (Region 4), the San Joaquin River (Region 5), and San Diego Creek (Region 8).

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 repellant, is registered with EPA and California (SWRCB, 1988c). Statewide, the use of endrin decreased in the ten year period to zero use in 1986 and 1987 (DFA, 1988 and 1989). Previously, from 1978 to 1982, a yearly average of 800 pounds were registered (DFA, 1980 through 1984). From 1983 to 1985, only 300 pounds per year were applied, primarily to vegetable seed and head lettuce (DFA, 1985 through 1987). The mammalian toxicity of endrin is the highest of the cyclodiene insecticides such as aldrin, dieldrin, endosulfan, heptachlor, and chlordane (USEPA, 1980c). Despite endrin's high toxicity, the parent compound is metabolized and excreted more readily than other organochlorine insecticides (USEPA, 1980c). Toxic metabolites such as 12-ketoendrin may persist, however. Limited use and rapid depuration may explain the infrequency of detection of endrin by the TSMP.

Endrin was detected in just over 3% of samples since 1978 and only in Regions 3, 4, 7, and 8. The NAS guideline for endrin was exceeded twice. The highest level found (120 ppb) occurred in a sample from the Old Salinas River (Region 3) in 1983. The other sample to exceed the guideline at 110 ppb was collected from the Alamo River (Region 7) in 1980. Endrin was detected for the first time in Region 4 in 1987. The FDA action level for endrin (300 ppb) was never exceeded.

Ethyl Parathion

Ethyl parathion is an organophosphate insecticide used primarily in California on almonds, prunes, peaches, nectarines, plums, oranges, and head lettuce. The statewide use of ethyl parathion has fluctuated, yet remained within the range of 640,983 pounds to 814,091 pounds from 1978 to 1987 (DFA, 1980 through 1989). The average yearly application was 738,242 pounds. In terms of usage, almonds were the largest single crop, comprising a yearly average of 30% of the total amount registered (DFA, 1980 through 1989). In California, ethyl parathion application to agricultural commodities requires a certified applicator. Parathion is considered acutely toxic to aquatic organisms (USEPA, 1986a).

The TSMP detected ethyl parathion at only three locations from 1978 to 1987. In 1985, it was detected in the Alamo River, Rice Drain 3, and Salt Creek Slough in Region 7. Ethyl parathion was also detected again in Rice Drain 3 in 1986. The highest concentration detected was 140 ppb in Rice Drain 3 in 1985.

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 (USEPA, 1980d) 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 (USEPA, 1980d). 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 (SWRCB, 1988c). The average use of heptachlor per year prior to 1986 was 30,000 pounds (DFA, 1980 through 1987). A peak of 111,415 pounds was applied in 1986 and followed by 83,201 pounds in 1987 (DFA, 1988 and 1989).

The parent compound, heptachlor, has been detected only once by the TSMP in 1980 in the Alamo River (Region 7). The primary metabolite, heptachlor epoxide, was detected in 4% of the samples. This substance was found in both urban and agricultural drainages in Regions 2, 3, 4, 5, and 8. All levels found were well below the NAS guidelines for both substances. Region 3 contained the highest number of samples with detectable levels of heptachlor epoxide. Most of these samples occurred in the Watsonville and the lower Salinas Valley areas between 1983 and 1987. The lower Santa Ana River in Region 8 is another area where the chemical is detected. The two highest values recorded statewide were observed in 1987 at Salinas Reclamation Canal in Region 3 (27 ppb) and Revolon Slough in Region 4 (22 ppb).

Hexachlorobenzene (HCB)

HCB, a wheat seed protectant, is no longer registered in California because of its high soil persistence. Commercial production of HCB in the United States was discontinued in 1976. No uses have been reported to the DFA for the last ten report years (DFA, 1980 through 1989). HCB may be present as impurities in other pesticides such as dacthal or pentachloronitrobenzene (SWRCB,1988d). While this compound is only slightly acutely toxic to mammals, it is a known carcinogen (USEPA, 1980e) and is listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act as both a carcinogen and a reproductive toxicant. The EPA has concluded that hexachlorobenzene has a high potential for bioconcentration in biota. Little is known of the acute aquatic toxicity of HCB (USEPA, 1980e).

HCB was found statewide in 16% of the samples collected from Regions 2, 3, 4, 5, 7, and 8 from 1978 to 1987. Concentrations ranged from 2.0 (detection limit) to 230 ppb found in 1985 in the New River (Region 7). As there are currently no standards for HCB, values are compared to the EDLs. The New River had 15 out of the 20 highest concentrations found statewide. Relatively high concentrations were also found in Salt Creek (Region 7) and the Salinas Reclamation Canal (Region 3).

Hexachlorocyclohexane (HCH) or Lindane

Four isomers of HCH (alpha-, beta-, delta-, and gamma-) are monitored by the TSMP. Gamma-HCH is also known as lindane and is the only isomer with a known use. The development of lindane was preceded by the use of a technical grade HCH, known as BHC, which was a mixture of five steroisomers. The production of lindane and the cancellation of BHC, also used as a pesticide, resulted from the discovery that the insecticidal activity of BHC was attributed solely to the gamma-isomer. Lindane degradation by soil microorganisms is slow. Lindane is capable of isomerization to alpha- and delta- forms by microorganisms and plants. The EPA has concluded that lindane is a human carcinogen (USEPA, 1985b). HCH was added to the State's list of chemicals known to cause cancer in compliance with the Safe Drinking Water and Toxic Enforcement Act of 1986.

Lindane is a multi-purpose insecticide and acaricidal chlorinated hydrocarbon used against pests of vegetable seeds, forest products, livestock, and cotton (USEPA, 1985b). In California, lindane is used primarily for structural and residential pest control. Other uses include landscape maintenance and protection of cotton. Lindane is currently classified as a California restricted use material which requires licenced, private and commercial applicators to obtain permits for application on agricultural commodities. No permits are required for home, structural, industrial, and institutional uses (SWRCB, 1988c). Average use of lindane was 38,383 pounds between 1978 and 1987, with peak years in 1979, 1980, and 1985, reaching 60,423 pounds (DFA, 1980 through 1989). Registered use decreased in 1986 and 1987 to a yearly average of 28,000 pounds.

Total HCH was detected in 14% of the samples from all regions, except Regions 1 and 6. Lindane was detected in 11% of the samples. Total HCH exceeded the NAS guideline in five samples collected in 1980, 1982, and 1987. Beta-HCH was the isomer found in four of the samples collected in 1980 and 1982 from the Alamo and New Rivers in Region 7. Lindane was detected in the fifth sample collected in 1987 from Revolon Slough in Region 4. The highest concentration found was 160 ppb beta-HCH in a 1982 sample from the New River. Beta-HCH has not been detected by the TSMP since 1982. Lindane was detected mainly in Regions 4 and 9. Samples from these two regions represent nearly 70% of the samples with detectable levels of lindane. Alpha-HCH was detected in most Regions in very low amounts. Delta-HCH has not been detected since 1983. This isomer was found only three times, twice in Region 5 and once in Region 8.

Nitrofen

Nitrofen is a contact herbicide, which is essentially insoluble in water. It is readily adsorbed by most soil types. Adsorption is reversible and not subject to leaching. It also readily photo decomposes to non-herbicidal products. Microbial breakdown is slow but it can be completely biodegraded to carbon dioxide in typical soils. Under conditions of use, nitrofen has been determined to be non-toxic to wild birds. Nitrofen is, however, toxic to fish. Application has been registered for vegetable crops, pre- and post- emergence on annual grasses and broadleaf weeds, and a small amount of landscape maintenance (Beste, 1983). Statewide application increased from 630,000 pounds in 1979 to 2,102,022 pounds in 1980 (DFA, 1981 and 1982). In 1981, only 1,079 pounds were registered with the DFA, followed by a yearly average of zero to four pounds from 1982 to 1987 (DFA, 1983 through 1989). Nitrofen was added to the State's list of chemicals known to cause cancer in compliance with the Safe Drinking Water and Toxic Enforcement Act of 1986.

The TSMP analyzed for nitrofen from 1978 to 1984, dropping it from the list of analyzed chemicals in 1985 due to its decline in use. Nitrofen was only detected twice throughout this six year period. The two samples, collected in 1979, were from the Alamo and New Rivers in Region 7. Channel catfish from the Alamo River near Calipatria contained 86 ppb nitrofen, while the same species from the New River near Westmorland contained 50 ppb.

Methoxychlor

According to the 1987 Farm Chemical Handbook (FCH, 1987), methoxychlor is used extensively as an agricultural, structural, home, and garden insecticide. There are presently no California or EPA use restrictions on methoxychlor (SWRCB, 1988d). There are few acute and chronic aquatic toxicity data for methoxychlor (USEPA, 1986a). However, the EPA reports a low accumulation rate and low toxicities for birds and mammals. The statewide use of methoxychlor, primarily for alfalfa crops and other agricultural uses, declined from 1978 to 1984, reaching a low of 8,791 pounds (DFA, 1980 through 1986). However, in 1985, an anomaly in the data showed a substantial increase in use of methoxychlor, indicated by a large amount used that year for structural pest control (DFA, 1987). The next two years agreed with the previous downward trend in use of methoxychlor to 837 pounds in 1987 (DFA, 1988 and 1989).

Methoxychlor was detected for the first time by the TSMP in fish tissue samples in 1987. It appeared at one station on the Salinas Reclamation Canal in Region 3 and at three sampling stations on San Diego Creek in Region 8. Residues in tissue ranged from 17 to 28 ppb. The detection limit is 15 ppb.

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 listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

PCBs were detected in 28% of the samples from all Regions, except Regions 1 and 6. The TSMP measures three congeners of PCB: 1248, 1254, and 1260. The most stable congener, PCB 1260, accounted for most of the detectable PCBs (20%). PCB 1248 has not been detected since 1985, while PCB 1254 was not detected at all in 1987. Total PCB exceeded the FDA tolerance level (2,000 ppb) three times since 1978. All three samples were collected in 1980 from the South Fork of the Feather River in Region 5. The Feather River area had a known PCB problem (see Regional Overview Chapter). The highest concentration detected at this site was 7,700 ppb in suckers. The South Fork of the Feather River also had the highest lipid weight concentration by far, over two parts per thousand. The NAS guideline was exceeded a total of 24 times since 1978. Samples exceeding the guideline were found in all regions where PCBs were detected. PCBs are regularly detected in the Guadalupe River area (Region 2), Salinas area (Region 3), Revolon Slough/Calleguas Creek area (Region 4), Harbor Park Lake (Region 4), Sacramento and San Joaquin Rivers (Region 5), New River (Region 7), Santa Ana River (Region 8), San Diego Creek (Region 9), and the Tijuana Estuary (Region 9).

Pentachlorophenol (PCP) and Tetrachlorophenol (TCP)

PCP and TCP are not part of the normal TSMP chemical scan. PCP is used primarily as a fungicide and bactericide in the treatment of wood products. Other uses for PCP include application along rights-of-way, landscape maintenance, and structural pest control. The manufacture of TCP has been discontinued. The EPA restricted the application of PCP to non-home use. In addition, the EPA required the registrants to reduce levels of approximately 10 contaminants in PCP products. Registrants were required to limit the dioxin contaminant to 1 ppm (USEPA, 1986d). This contaminant causes tumors in rats and mice (USEPA, 1986d). PCP is listed by the State as a known carcinogen pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Regions 1 and 8 requested PCP and TCP analysis (Table 13). Seven stations were monitored for these substances in Region 1 from 1984 to 1987. Only the Santa Ana River was monitored in Region 8. Three samples were analyzed from this River in 1985. PCP was detected four times in Region 1 and only once in Region 8. The highest concentration found was 7.2 ppb. TCP was detected only twice, both times in the Mad River (Region 1). The highest concentration of TCP detected was 2.6 ppb.

Pentachloronitrobenzene

Like HCB, pentachloronitrobenzene (PCNB) was introduced as a dressing effective against wheat smut and bunt. Present uses also include fumigation of soil for the protection of cotton and a variety of vegetables. PCNB is also applied for landscape maintenance. There are no use restrictions in California for PCNB (SWRCB, 1988d).

The TSMP analyzed for PCNB from 1978 to 1984 after which it was dropped from the routine scan. PCNB was detected only once, in 1979, in the Alamo River near Calipatria (Region 7). Channel catfish from this station contained 10 ppb.

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs are a diverse group of compounds consisting of substituted and unsubstituted polycyclic and heterocyclic aromatic rings. PAHs are not part of the routine chemical scan conducted by the TSMP. In 1987, however, two stations in Region 5 (Sacramento River near Hood and the San Joaquin River near Vernalis) were monitored for 22 PAHs (SWRCB, 1989). Largemouth bass and carp from the Sacramento River and white and channel catfish from the San Joaquin River were analyzed. PAHs were not detected at either station.

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 (SWRCB, 1982b). 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 (SWRCB, 1988c). There has been a substantial decrease in use of toxaphene, evidenced by 1,025,098 pounds registered in 1978 to 647 pounds registered in 1987 (DFA, 1980 through 1989). The average use in the latter four years (1984-1987) was 41,616 pounds. In 1986, 93% of the registered pesticide was applied to clover and, in 1987, 96% to cotton and alfalfa, indicating a decreasing application to food crops.

Toxaphene was detected in 22% of the samples statewide. Toxaphene was not detected in Regions 1, 2, 6, and 9. The FDA action level for toxaphene (5,000 ppb) was exceeded in three channel catfish samples collected from the San Joaquin River near Vernalis in 1983, 1984, and 1986. The highest concentration yet detected (14,000 ppb) occurred at this station in 1984. Both the detection limit and the NAS guideline for toxaphene is 100 ppb, so all samples with detectable levels of toxaphene will exceed the guideline. Toxaphene was detected most often in Regions 3 and 7 with 45% and 41% of the samples, respectively, containing the chemical. Areas where toxaphene was regularly detected include: the Salinas and Watsonville areas (Region 3); Revolon Slough and Calleguas Creek (Region 4); the Sacramento, San Joaquin, Stanislaus, Tuolumne, and Merced River Drainages (Region 5); the Alamo and New Rivers (Region 7); and San Diego Creek (Region 8). Over the years, consistently high values were found in the San Joaquin River near Vernalis. The highest lipid weight values were found in Revolon Slough. There is no evidence to suggest a decrease in the detection levels of toxaphene statewide even though the use of toxaphene pesticides has decreased.

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 (NAS, 1973). Included in this group of pesticides, termed Chemical Group A, are aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene.

Chemical Group A, with the exception of two samples, exceeded the guideline when at least one pesticide in the group exceeded its guideline. The first exception was a 1985 sample from Harkins Slough upstream from Watsonville Slough (Region 3). The sum of chlordane (58 ppb) and dieldrin (62 ppb) found in this sample exceeded the Chemical Group A guideline. The second exception was a 1987 sample from Calabasas Creek at Tasman Drive (Region 2). Chlordane found in Calabasas Creek nearly exceeded the individual guideline at 99 ppb. With the addition of dieldrin (22 ppb) and heptachlor epoxide (9.9 ppb), the sample exceeded the group guideline. For the most part, Chemical Group A has not identified additional problems that were not already uncovered by review of the individual pesticides.

Trace Elements (Metals)

Arsenic

Arsenic is a concern as a surface water pollutant because of its human carcinogenicity, persistence in the environment, and potential for bioaccumulation in aquatic organisms (SWRCB, 1984a). Arsenic is listed as a known carcinogen by the State pursuant to the Safe Drinking Water and Toxic Enforcement Act of 1986. Arsenic may reach surface waters from natural sources of this trace element or by agricultural application of arsenical pesticides. Investigation by the State Board of arsenic levels in the San Joaquin Valley concluded that use of arsenical pesticides may increase the concentrations in drainage waters and sediments (SWRCB, 1984a). While most uses of inorganic arsenical pesticides have been cancelled by the DFA, use of organic arsenicals which can be converted to the more toxic inorganic form is unrestricted. From 1981 to 1987, the total combined arsenical pesticide usage statewide ranged from 103,879 pounds to a high of 311,632 pounds in 1984 (DFA, 1983 through 1989). The average yearly application for the last seven years was 164,000 pounds. Usage in 1986 and 1987 was 144,680 and 213,794 pounds, respectively. Three arsenic-based pesticides used in recent years were predominant: sodium arsenite, cacodylic acid, and monosodium methanearsonate (MSMA). In 1986 and 1987, these three pesticides represented all but about 600 pounds of the total registered use for each of those years (DFA, 1988 and 1989). Sodium arsenite was applied solely to grapes. Cacodylic acid and MSMA were used for cotton, landscape maintenance, rights of way, and other non-agricultural purposes. Another arsenic-based pesticide, disodium methanearsonate (DSMA), was used relatively extensively in the early 1980s but has decreased to just a few hundred pounds in 1986 and 1987 (DFA, 1980 through 1989). Other arsenic-based pesticides used in small amounts include arsenic pentoxide, arsenic trioxide, and lead arsenate.

Arsenic was detected in 59% of the samples collected statewide from 1978 to 1987. Starting in 1985, the analytical method used to detect arsenic was improved resulting in better recovery and a lower detection limit. Following the change in method, the number of samples with detectable levels of arsenic increased from 52% from 1978 to 1984 to 79% from 1985 to 1987. However, the lower detection only partially explains the increase in the number of samples containing arsenic. In the latter three years, only 18 samples out of 145 analyzed (12%) contained levels of arsenic below the original detection limit. Arsenic was detected most often in Region 9 (85% of the samples) followed by Region 2 (82%) and Region 1 (76%). Nearly 79% of the concentrations exceeding the EDL 95 were measured between 1985 and 1987. Not surprisingly, most of the levels above the EDL 95 were found in Regions 2, 5, and 9. The increased incidence of high arsenic levels from 1985 to 1987 is thought to be more indicative of a widespread pollution problem rather than the result of the improved recovery method. The percent increase in recovery does not fully explain the dramatic increase in arsenic levels. Recent high levels of arsenic were found in the following areas: Suisun Bay (Region 2); Kings River, Black Butte and Stony Gorge Reservoirs (Region 5); and the Tijuana Estuary (Region 9). Other areas with high arsenic levels include: Lake Nacimiento (Region 3), Puddingstone Reservoir (Region 4), and San Dieguito Lagoon (Region 9). The two highest levels of arsenic detected, 7.4 and 5.9 ppm, were found in 1987 samples of diamond turbot, a saltwater species from the San Dieguito Lagoon and the Tijuana Estuary, respectively. The highest freshwater concentration was 1.9 ppm found in an asiatic clam sample collected in 1979 from the Colorado River (Region 7). This clam sample, along with three other clam samples, exceeded the MIS of 1.4 ppm for arsenic in shellfish. The other three samples were collected from the Colorado River in 1978 (Region 7) and the Feather River and the Kings River in 1979 (Region 5). These three samples contained 1.58, 1.4, and 1.4 ppm, respectively.

Cadmium

Cadmium is one of the most toxic trace elements analyzed by the TSMP. Cadmium may be elevated in surface water due to fallout from air pollution, industrial discharge, or municipal effluent (USEPA, 1985a). 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 (USEPA, 1985a). Furthermore, the TSMP has detected higher cadmium levels in rainbow trout and largemouth bass, suggesting that these species may accumulate higher levels in the liver. These factors indicate the difficulty in determining the exposure and impact of cadmium on aquatic organisms and their predators. Cadmium is a known human carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Nearly all samples analyzed (94%) contained detectable levels of cadmium. Lake San Antonio (Region 3) and the Keswick area of the Sacramento River (Region 5) have been identified in previous TSMP reports as cadmium "hot spots". The 13 highest cadmium levels statewide were found at these two sites. All eight bass samples collected from Lake San Antonio from 1982 to 1985 had levels above the EDL 95. The two highest concentrations of cadmium, 6.7 and 6.6 ppm, were measured in largemouth bass from the Lake in 1982 and 1983, respectively. The State Board's Mussel Watch Program (SMWP) has also reported elevated cadmium levels in freshwater clams from Lake San Antonio (SWRCB, 1988b). The source for the cadmium is unknown. All but one of the eight rainbow trout samples analyzed from the Keswick area of the Sacramento River contained cadmium levels above the EDL 95. Iron Mountain Mine and other mines in the area have been identified as sources for elevated metal levels in this stretch of the river. Other areas where elevated cadmium levels were detected include Shasta Lake (above Keswick) and Merced River in Region 5, and San Diego Creek in Region 8. Two whole samples of red shiner collected from San Diego Creek in 1983 and 1987 exceeded the EDL 95 for whole fish.

Chromium

Elevated chromium concentrations have been detected by the TSMP in watersheds where probable sources of chromium are mine drainage, agricultural runoff, and industrial discharge (SWRCB, 1986). Chromium-enriched water from acid mine waste has elevated chromium concentrations in both the Sacramento River and the San Joaquin River. Agricultural runoff may contain chromium-based fungicides which have been used to preserve wood and to control diseases of turf (FCH, 1987). Industrial uses of hexavalent chromium salts include metal plating, aluminum anodizing, leather tanning, and the manufacture of paints, explosives, ceramics, and paper. The textile, ceramic, glass, and photographic industries utilize trivalent chromium in their processing. The bioavailability and toxicity of chromium depends on the metal's oxidation state, pH, hardness, and salinity. The toxicity of chromium to fish species is variable. Salmonid species are 100 times more sensitive than carp, bluegill, and fathead minnows (USEPA, 1984). Because chromium is accumulated in gills, liver and kidney rather than muscle, fish usually die before accumulating toxic levels of chromium in edible tissue (Jaworski, 1985). Therefore, the potential for biomagnification is low. Hexavalent chromium is a mammalian carcinogen listed by the state pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Chromium was detected in 31% of the samples from 1978 to 1987. Region 1 had the highest rate of detection with 50% of the samples containing chromium followed by Region 8 with 41%. Only 3% of the samples in Region 6 had detectable levels of chromium. Such a low rate of detection in Region 6 is not surprising as agricultural pesticide use and industrial discharges are not prevalent in the Region. The highest chromium concentrations were found in invertebrates (28 out of the 30 highest concentrations) collected in Regions 1 and 5. Fifteen freshwater clam and mussel samples collected from 1978 to 1980 in these two Regions equaled or exceeded the MIS of 1.0 ppm. The highest chromium level detected statewide was 2.1 ppm in a freshwater mussel sample from the Klamath River (Region 1). The highest fish tissue concentration of chromium (0.71 ppm) was detected in a 1987 whole sample of fathead minnow from Coyote Creek. Nearly 70% of the fish samples above the EDL 95 came from Region 5. More than half (7 samples) of the EDL 95 exceedances in Region 5 were found in the Sacramento River. Other areas with tissue levels above the EDL 95 include: Hardscrabble Creek and the Russian River (Region 1), Coyote Creek (Region 2), Chorro Creek (Region 3), the San Gabriel River (Region 4); and the American, Feather, McCloud, Mokelumne, and Stanislaus Rivers (Region 5). At five of these stations (American, Feather, Mokelumne, Stanislaus, and Russian Rivers), exceedances were detected in 1978 samples. Subsequent sampling in later years found chromium levels near or below the detection limit at these five stations.

Copper

Copper in aquatic biota is widespread throughout the state. Elevated copper concentrations may result from industrial effluent, algal control efforts, or mine runoff. Metallic copper or copper salts are used in alloy manufacture, the electrical industry, textile processes, pigmentation, tanning, photography, engraving, and electroplating. Copper is also a component of certain insecticides and fungicides. Mine wastes have been implicated as the source of elevated copper in the upper Sacramento River. Elevated copper in surface waters is a potential pollution hazard to aquatic organisms. Exposure of freshwater organisms to less than 10 ppb results in chronic toxicity symptoms (USEPA, 1980a). Copper does not appear to bioconcentrate in the edible tissue of freshwater organisms to any significant degree. This low bioconcentration factor and the relatively low mammalian toxicity reduces the potential human health risk from ingestion of freshwater fish (USEPA, 1980a).

Copper was detected in all but one sample analyzed in the TSMP. A largemouth bass sample collected from the American River (Region 5) did not contain any detectable copper. Copper is a metal whose uptake and accumulation seems to be more species dependent than other metals. Trout are known to accumulate copper in the liver to a much higher level than other species. Because of this, trout are treated separately in the TSMP and ranked only against other trout when calculating the EDLs for copper. Like trout, white bass seem also to accumulate copper to high levels. The three highest concentrations of copper yet found (600, 480, and 445 ppm) were measured in white bass from Lake Nacimiento (Region 3) in 1984, 1985, and 1981, respectively. Largemouth bass and other species collected from the Lake during that same time period never exceeded 11 ppm. White bass are now thought to be found only in Lake Nacimiento in California after having been removed by the DFG from the Kings River drainage in Region 5. In the future, white bass will probably be considered separately from other species. The MIS for copper (20 ppm) was exceeded once (84 ppm) in a 1980 freshwater clam sample from the Feather River (Region 5). Copper levels exceeding the EDL 95 for trout all occurred in rainbow trout from the Sacramento River (Region 5) near Keswick (2 samples) and downstream from Shasta Dam (1 sample) in 1983 through 1985. The highest level was 350 ppm from the Shasta Dam station. The long term trend at the Keswick station suggests a decrease in copper levels from a high of 330 ppm in 1984 to a low of 150 ppm in 1987. Elevated copper levels in trout were also found in Region 6 in the East Walker River, Hot Creek, and Carson River. Non-trout exceeding the EDL 95 were dominated by white bass from Lake Nacimiento and the Kings River area. Other areas where the non-trout EDL 95 was exceeded included: Suisun Bay (Region 2), Salinas River (Region 3), the San Gabriel River (Region 4), and Beach Lake and McCloud River (Region 5). The highest level found in a non-trout, non-white bass sample was in a 1984 striped mullet sample from the Tijuana Estuary (Region 9). Crayfish were also found with high levels of copper from the San Joaquin River near Vernalis (154 ppm) and the Sacramento River near Hood (108 ppm) in Region 5 Both crayfish samples were collected in 1980.

Lead

Lead is moderately toxic to aquatic organisms. Lead is a known human reproductive toxicant in humans and two lead salts, lead acetate and lead phosphate, are human carcinogens. Lead is listed as a reproductive toxicant by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act. Urban runoff and industrial effluents can contribute to lead loading. A variety of lead salts are used extensively in industry, although the largest source contributing to surface water runoff in urban areas is thought to come from leaded gasoline (USEPA, 1980b).

Lead was detected in 31% of the samples collected since 1978. In recent years, however, the rate of detection has decreased. From 1978 to 1983, about 40% of the samples contained detectable levels of lead. This rate decreased to 19% from 1984 to 1987. The widespread use of unleaded gasoline is probably one reason why lead is not detected as frequently. One Region seems to be going against this trend. Region 9 had the highest rate of detection of lead of any Region in both time periods (57% and 45%, respectively). The database for Region 9, is, however, limited to just 27 samples from 1978 to 1987. Every Region had at least one sample containing lead concentrations exceeding the EDL 95. Most of these samples (82%) were collected before 1984, again confirming that lead levels are decreasing in the environment. Region 5 had the most samples exceeding the EDL 95. Most of these samples were found in the Sacramento and San Joaquin River drainages. In Region 3, samples collected from 1984 to 1987 did not have any detectable levels of lead. Since 1985, high lead levels were detected in samples from San Leandro Creek and Lake Herman (Region 2), the San Gabriel River (Region 4), Stockton Deep Water Channel (Region 5), Grass Valley Lake (Region 6), and Alvarado Creek and the Tijuana Estuary (Region 9). The highest level of lead (1.1 ppm) occurred in a whole sample of threespine stickleback from San Leandro Creek near the Highway 17 Bridge in 1986.

Mercury

Mercury is the most toxic of the trace elements analyzed by the TSMP. It is acutely toxic to aquatic organisms at levels less than 3 ppb (USEPA, 1986a). Mercury bioaccumulates in fish to levels that are hazardous to human health. Previous monitoring by the TSMP has found levels above the FDA action level of 1.0 ppm in waterbodies of central California and along the north coast. Possible sources of mercury are the naturally occurring cinnabar deposits and related mining activities in the coast range, and past gold mining activities in the Sierra foothills.

Mercury was detected in nearly all samples (97%) analyzed from 1978-87. More samples were analyzed for mercury than for any other substance in the TSMP. Almost 300 individual fish samples from Regions 2, 3, and 5 were analyzed as part of special intensive surveys for mercury. Surveys were conducted in Lake Nacimiento (Region 3) in 1982 and 1983, Clear Lake (Region 5) in 1983, Lake Berryessa (Region 5) in 1985, and the Guadalupe River area (Region 2) and Lake Herman (Region 2) in 1986. In addition, individual samples were analyzed for mercury as part of an interlaboratory comparison study with the Davis Creek Reservoir (Region 5) research group. Over 70% of the survey samples collected from Lake Nacimiento exceeded either the FDA action level of 1.0 ppm or the MIS of 0.5 ppm. Twenty-five percent of the survey samples in Lake Berryessa and over 40% of those in Clear Lake had mercury concentrations at least above the MIS. All but four of the 106 samples from five stations in the Guadalupe River area exceeded at least the MIS, of which, 72% were above the FDA action level. The waterbodies with high mercury levels in the Guadalupe River area include: Guadalupe River, Guadalupe Reservoir, Guadalupe Creek, Calero Reservoir, and Alamitos Creek. Lake Herman mercury levels were also high with all but one of the 20 samples exceeding at least the MIS. Samples analyzed from Davis Creek Reservoir were above the FDA action level in all but one sample. In all cases, the high mercury levels were due to past mining activities. Because of these high levels, the DHS issued fish consumption health advisories for all the waterbodies mentioned, except Davis Creek Reservoir, which is on private property. The highest level detected statewide was 3.8 ppm in a 1986 bluegill sample from Guadalupe Reservoir. Periodic exceedances of mercury criteria occurred in the American, Feather, and Sacramento Rivers. Periodic exceedances may be due to fluctuating water levels. Other areas in recent years with high mercury levels were all in Region 5 and include: Beach Lake, Rollins Reservoir, East Park Reservoir, Don Pedro Reservoir, the San Joaquin River, Pardee Reservoir, and Cross Canal. Cross Canal was misidentified in previous reports as Sacramento Slough. High levels found in many of these waterbodies were probably due to historic gold mining activities during the gold rush era. Mercury was used during that time in gold processing.

Nickel

Nickel can enter surface waters from natural sources, mine runoff, or municipal and industrial effluents. Elevated concentrations of nickel have been reported by the TSMP in the northern coastal range. Natural nickel deposits are not readily bioavailable because of nickel's low solubility in water. However, nickel may be mobilized by acidification from acid mine waste. Urban or industrial sources of nickel include electroplating processes, fossil-fuel refining, and heavy fuel oil combustion. Nickel has a relatively low aquatic toxicity compared to the other trace elements monitored by the TSMP. Nickel, however, is a known human carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Nickel was detected in 24% of the samples statewide. Region 1 had the highest detection rate with 66% of the samples containing nickel. Region 6 had the lowest rate of detection with only one sample, collected from the Truckee River in 1979, containing nickel. A majority of the highest nickel concentrations found statewide occurred in invertebrates such as freshwater mussels and clams and in crayfish collected in the early years of the program. Many of these high levels occurred in Regions 1 and 5. Crayfish collected from the Alamo River near Calipatria (Region 7) in 1980, had the highest nickel concentration (3.2 ppm) yet found. Almost all the EDL 95 exceedances in fish occurred in Regions 1 through 5. One sample from Region 7 exceeded the EDL 95. Close to 50% of the EDL 95 exceedances occurred in Region 1. Rainbow trout from Hardscrabble Creek in Region 1 collected in 1984 contained the highest nickel concentration found in fish at 2.2 ppm. Another station in Region 1, the Klamath River near Klamath Glen, had high nickel levels in sculpin collected in 1978 and 1979. Further sampling at this station showed a decline in nickel levels to slightly above the detection limit in 1984, the last year the station was sampled. Bass from Lake Nacimiento (Region 3) exceeded the EDL 95 in 1981. Additional sampling in later years failed to detect nickel in any sample. This pattern is also true for the Alamo River (Region 7). In recent years, high nickel concentrations were detected in Suisun Bay and Guadalupe River (Region 2), Chorro Creek (Region 3), the San Gabriel River (Region 4), and the Sacramento River near Keswick (Region 5).

Selenium

Toxicity of selenium to aquatic organisms and their predators has been a statewide concern since it was identified as the element responsible for embryonic abnormalities in birds from Kesterson National Wildlife Refuge. Subsequent investigation by the TSMP indicated elevated selenium levels in agricultural drains and the Salton Sea in Region 7. The DHS has issued fish consumption health advisories for both the Grassland area surrounding Kesterson and the Salton Sea. Selenium is an essential mineral. Its toxicity is affected by its oxidation state. The two main sources of selenium in nature are coal deposits and marine shales. Identified sources of selenium pollution include effluents from oil refineries and concentration of seleniferous soils via agricultural practices.

Selenium was detected in nearly all (98%) of the samples for which it was analyzed in the TSMP. Routine analysis for selenium did not begin until 1984. Regular analysis in filet samples was initiated in 1985. High levels of selenium exceeding the MIS of 2.0 ppm were found almost exclusively in Region 7.

The Kesterson National Wildlife Refuge in Region 5, was sampled only twice by the TSMP in 1984. Mud Slough in Region 5 and Irvine Park Lake in Region 8 were the only stations outside Region 7 with selenium levels equaling or exceeding the MIS. Both samples were collected in 1987. In Region 7, 30% of the samples equaled or exceeded the MIS. All but one of the 16 samples collected from the Salton Sea exceeded the MIS. Orangemouth corvina from the Sea had 8 out of the 10 highest filet selenium concentrations. The highest concentration in filet (4.6 ppm) was detected in a sample of Mozambique mouthbrooders from Forgetmenot Drain. Seven out of 10 Salton Sea drainages where filet samples were analyzed had samples equaling or exceeding the MIS. The three remaining drainages had samples with selenium levels above 1.0 ppm. Besides the Salton Sea drainage, high selenium levels in fish were also found in both the northern and southern reaches of the Colorado River along California's border. Lake Havasu and the Palo Verde Outfall Drain along the Colorado River were identified as areas of concern for selenium. Besides fish, the MIS of 0.3 ppm for shellfish was exceeded in four 1987 samples of transplanted freshwater clams (TFC) from the Russian River area in Region 1. This was the first time TFC were used in the TSMP. Most selenium in Region 7 is thought to come originally from the Colorado River, which supplies water to the Imperial Valley for agricultural purposes.

Silver

Silver is highly toxic to aquatic organisms, ranking as one of the most toxic of the trace elements analyzed by the TSMP. Elevated silver levels in California are associated with heavy industry or mining activities. Metallic silver is used in alloys, electroplating, food processing, and the beverage industry. Silver nitrate is used in photography, the ceramics industry, and electroplating. In 1987, a change in instrumentation increased the sensitivity of detection of silver, thereby reducing the detection limit from 0.02 to 0.01 ppm. Nearly 51% of the samples in 1987 had detectable levels of silver, an increase from the 32% detection frequency in 1986. Since 10 of the 55 (15%) samples analyzed in 1987 were at or below the previous detection limit, this increase can be attributed to the change in instrumentation.

Overall, silver was detected in 37% of the samples collected statewide from 1978 to 1987. Region 6 had the highest rate of detection with 80% of the samples containing silver. Region 4 had the lowest detection rate (15%) with only four samples containing silver. Three of the four samples from Region 4 came from the San Gabriel River and exceeded the EDL 95. Tilapia collected in 1985 from this river contained the highest silver concentration (4.1 ppm) ever found statewide. The EDL 95 for silver was exceeded in Regions, 1, 3, 4, 5, 6, and 9. Brown trout from the East Walker River (Region 6) exceeded the EDL 95 all but one of the six times it was sampled. Silver levels in the river, however, appear to be declining from a high of 1.1 ppm in 1983 to a low of 0.57 ppm in 1987. The McCloud River (Region 5) also contained high levels of silver in brown trout in 1978 and 1979. Brown trout collected in 1987 from this station contained less than half as much silver as previous levels. Higher flows in the early years of the Program may be one reason certain areas had higher silver levels then they do now. More metal-laden sediment may have washed into streams in the wetter years. Other areas where high silver levels were found include: Big Lagoon (Region 1), Lake Nacimiento (Region 3), Lake Kaweah (Region 5), Hot Creek (Region 6) and the Tijuana Estuary (Region 9).

Zinc

Zinc is an essential trace mineral and, at high doses, it is acutely toxic to freshwater species. The toxicity and bioavailability of zinc depends on physical and chemical characteristics such as pH, salinity, temperature, and turbidity. Elevated zinc concentrations in surface waters have been associated with mine runoff and industrial effluent. Zinc has many uses, including electroplating and alloy manufacturing, and is a component of many products such as cosmetics, pharmaceutics, dyes, paint, and insecticides.

Zinc was detected in all samples analyzed by the TSMP. High levels of zinc in fish, exceeding the EDL 95, were found in Regions 1, 2, 3, 5, 6, and 9. The highest zinc concentrations detected statewide were 74 and 67 ppm found in 1980 crayfish samples from the Colorado River (Region 7) and the San Diego River (Region 9), respectively. The highest concentration of zinc in fish was 60 ppm in a 1979 brown trout sample from the McCloud River (Region 5). In 1987, zinc was found at a much lower concentration in a brown trout sample from this station. The Eel River (Region 1) also exceeded the EDL 95 in a 1978 sculpin sample. Since then, samples from the Eel River have been at or below the EDL 85. The Truckee River is another example with high zinc concentrations in samples collected early in the TSMP years and lower concentrations found in later years. Like silver, high zinc levels in earlier years at certain stations may be due to flows that carried more metal-laden sediments. In recent years, high zinc levels were found at the following locations: Alameda Creek near Shinn Pit, San Leandro Creek, and Suisun Bay (Region 2); Chorro Creek and Lake Nacimiento (Region 3); Beach Lake (Region 5); East Walker River (Region 6); and the Tijuana Estuary (Region 9).

APPENDIX B (continued)

Toxic Substances Monitoring Program
1978 - 1987 Station Descriptions

Station Number	Station Name	County	Description
205.50.07	CALABAZAS CR/D/S TASMAN DR	Santa Clara	Station located from 50 yards downstream to 300 yards upstream of Tasman Drive.
205.50.09	GUADALUPE R/HOWARD ST	Santa Clara	Station located near the foot of Howard Street in San Jose.
206.50.14	NAPA R/NAPA	Napa	Station located on Oak Knoll Avenue off Highway 29 north of the city of Napa.
206.60.01	SAN PABLO CREEK	Contra Costa	Station located from Third Avenue to 1/2 mile upstream in the city of San Pablo
207.10.90	SUISUN BAY	Solano	Station located throughout Suisun Bay.
207.21.03	LAKE HERMAN	Solano	Station located in Lake Herman.
304.12.06	SAN LORENZO R/BIG TREES	Santa Cruz	Station located near the bridge at the entrance of Henry Cowell State Park.
304.12.08	BEAN CR/GRAHAM HILL RD	Santa Cruz	Station located on Bean Creek at Graham Hill Road near the confluence with the San Lorenzo River.
304.12.09	SAN LORENZO R/GRAHAM HILL RD	Santa Cruz	Station located on the San Lorenzo River at the Graham Hill Road Bridge.
304.12.10	SAN LORENZO R/ZAYANTE CR	Santa Cruz	Station located on Zayante Creek by East Zayante Road near the railroad trestle
304.12.11	BEAN CR/CONFERENCE DR	Santa Cruz	Station located along Conference Drive on Bean Creek, a tributary of the San Lorenzo River.
304.12.12	NEWELL CREEK	Santa Cruz	Station located on Newell Creek, a tributary of the San Lorenzo River.
304.12.16	LOCH LOMOND	Santa Cruz	Station located along the east shore of Loch Lomond Reservoir on Newell Creek, a tributary of the San Lorenzo River.
305.10.02	WATSONVILLE SL/SAN ANDREAS RD	Santa Cruz	Station located between conjunction of Harkins Slough to 1/4 mile downstream of San Andreas Road Bridge.
305.10.03	PAJARO R/D/S HWY 1 BRG	Monterey/ Santa Cruz	Station located along the Monterey/Santa Cruz County line about 1-1/2 miles downstream of the Highway 1 Bridge, between Watsonville's sewage treatment plant and the Therwachter (McGowan Rd.) Bridge.
305.10.04	HARKINS SL/U/S WATSONVILLE SL	Santa Cruz	Station located at the confluence of Harkins Slough and Watsonville Slough and extending upstream about 1/2 mile.
305.10.05	WATSONVILLE SL/U/S HARKINS SL	Santa Cruz	Station is located at the confluence of Watsonville Slough and Harkins Slough and extending to above the railroad track.

APPENDIX B (continued)
Toxic Substances Monitoring Program
1978 - 1987 Station Descriptions

Station Number	Station Name	County	Description
305.10.06	WATSONVILLE SL/HARKINS SL RD	Santa Cruz	Station located in the pool area above Harkins Slough Road.
305.20.00	PAJARO R/HWY 129 BRG	Santa Cruz	Station located on the Pajaro River at Highway 129 Bridge overcrossing.
305.50.59	LAKE HERNANDEZ/D/S DAM	San Benito	Station located downstream of the dam at Lake Hernandez.
305.50.60	LAKE HERNANDEZ/SAN BENITO R	San Benito	Station located in Lake Hernandez on the San Benito River.
306.00.00	MOSS LANDING HARBOR	Monterey	Station located at a private dock just west of the Shell Oil Co. service dock and boat ramp.
306.00.90	CALCAGNO #4	Monterey	Station located in the Calcagno field adjacent to and north of Moro Cojo Slough and downstream of the railroad crossing.
306.00.91	F DOLAN #4	Monterey	Station located in the Dolan field adjacent to Moro Cojo Slough downstream of the Calcagno field.
307.00.19	SAN CLEMENTE RES	Monterey	Station located on the San Clemente Reservoir.
309.10.00	SALINAS R LAGOON	Monterey	Station located on the southern shore of the lagoon near the flow control structure at the southern terminus of the Old Salinas River.
309.10.02	LOWER TEMBLADERO SL	Monterey	Station located approximately one to two miles upstream of the Slough's confluence with the Old Salinas River.
309.10.03	OLD SALINAS R/MOLERA RD	Monterey	Station located where the river channel is nearest Molera Road, upstream of Station 309.10.04 about 1/2 mile.
309.10.04	OLD SALINAS R/MONTEREY DUNES BRG	Monterey	Station located at the Monterey Dunes Way Bridge.
309.10.05	SALINAS R/BLANCO DRAIN	Monterey	Station located about 1/2 mile downstream of the Blanco Drain discharge to the Salinas River.
309.10.07	SALINAS R/BLANCO RD	Monterey	Station located approximately 1/4 to 3/4 mile downstream of Blanco Road.
309.10.08	ESPINOSA SLOUGH	Monterey	Station located about 1/2 mile upstream of the State Highway 183 Bridge.
309.10.09	BLANCO DRAIN/SALINAS R	Monterey	Station located in the 100-yard stretch immediately upstream of the drain's confluence with the Salinas River.
309.10.11	BLANCO EAST/PUMP STATION	Monterey	Station located on Blanco Drain east of pumping station.

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*										
305.10.02											12000.0#	14287.8#
305.10.03											2300.0#	3730.0#
305.10.04						2.7*						
305.10.04											710.0#	1466.0#
305.10.05												120.0#
305.10.05											1500.0#	2101.6#
305.10.06											510.0#	1403.0#
309.10.00										676.0#		335.8#
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.

TOXIC SUBSTANCES MONITORING PROGRAM

1988-89

91-1WQ
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California Department of Fish and Game

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

CHEMICAL ASSESSMENTS

This chapter summarizes the 1988-89 results for each organic chemical and trace element (metal) detected. A description of each and its uses are provided along with an overall discussion of results. Stations where organic chemicals or trace elements exceeded criteria are presented by region in Chapter 4 - Regional Assessments (Tables 12 through 21) and also are summarized statewide in Appendices H, I, and J. References to chlordane, DDT, endosulfan, HCH, and PCB concentrations are to be considered total concentrations unless otherwise specified.

Organic Chemicals

Chlordane

Chlordane is a mixture of chlorinated hydrocarbons used alone or in combination with heptachlor for subterranean termite control. It has also been used for residential and garden pests and for controlling soil insects in field crops such as grapes, citrus, and strawberries. Before 1986, the statewide application of chlordane, as a pesticide, averaged approximately 200,000 pounds per year (DFA 1980 through 1988). Registered amounts of chlordane subsequently rose to over 500,000 pounds in 1986 and over 600,000 pounds in 1987 (DFA 1988 and 1989). However only 16,000 pounds were registered in 1988, of which, 98% was applied for structural pest control and landscape maintenance (DFA 1990). Prior to December 1987, existing stocks of all chlordane and heptachlor termiticides could be applied consistent with label instructions (SWRCB 1988b). From December 1987 to April 1988, these termiticides could be applied only by certified operators. 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.

In 1988-89, total chlordane was detected in 34% of the samples collected statewide. This frequency is less than the 45% found from 1978 to 1987. Region 2 had the highest frequency of detection in 1988-89 with 69% followed by Region 8 with 52% Chlordane was not detected in Region 1 in 1988-89. The three most predominant chlordane isomers found were trans-nonachlor, trans-chlordane and cis-nonachlor. The FDA action level was exceeded 3 times in goldfish from Region 4, once at the Rio de Santa Clara station (1,916 ppb) and twice at Harbor Park Lake (576 and 484 ppb). These 3 goldfish samples were among the ten highest concentrations found since 1978. The NAS guideline for chlordane was exceeded a total of seven times, twice at Paradise Cut in Region 5, three times at San Diego Creek in Region 8, and twice at Peters Canyon Channel also in Region 8. All the above mentioned areas have a history of high chlordane levels, particularly Harbor Park Lake which has exceeded the FDA action level four times since 1983 and has the two highest concentrations yet measured. The highest chlordane concentration found in 1988-89 was the 1,916 ppb found in goldfish from the Rio de Santa Clara station. This was also the third highest concentration of chlordane found to date. Although chlordane continues to be found at high levels at a number of sites in the State, levels overall should start to decrease with the banning of the chemical.

Chlorpyrifos

Chlorpyrifos, an insecticide sold as Dursban, Lorsban, and Stipend, has extensive home and agricultural application. Dursban is applied for the control of household insects such as ants, cockroaches, termites, and ornamental plant insects as well as for the control of cattle flies. Lorsban is both a soil and foliar insecticide applied to corn, alfalfa, fruit trees, nuts, and other vegetable crops. Stipend is used primarily on mushrooms for fly control (FCH 1989). Other reported uses include control of mosquitos in wetlands and turf-destroying insects on golf courses (Odenkirchen and Eisler 1988). The EPA considers chlorpyrifos extremely toxic to fish, birds, and other wildlife (USEPA 1986a). However, at present there are no California or EPA use restrictions for chlorpyrifos (SWRCB 1988b).

The statewide use of chlorpyrifos has increased over the years, reaching 1,000,000 pounds in 1987 and 1,700,000 pounds in 1988. Usage in 1988 was over 30 times that of 1978 (55,000 lbs). In 1987 and 1988, the primary uses of chlorpyrifos were for control of structural pests and pests on cotton and alfalfa (DFA 1989 and 1990). Other important applications of chlorpyrifos include sugarbeets, oranges, lemons, almonds and varied other fruit and vegetable crops (DFA 1980 through 1990). Chlorpyrifos was by far the most widely used of the pesticides monitored in the Program since 1984.

Chlorpyrifos was detected in 11% of the samples in 1988-89 down from 18% in 1987. From 1978 to 1987, chlorpyrifos was detected in 8% of the samples. Only Regions 5, 7, and 8 had detectable levels of chlorpyrifos in 1988-89 with most detections occurring in Region 7. The EDL 95 was exceeded in samples from all three Regions. The highest concentration found in 1988-89 (380 ppb) was in a 1989 channel catfish sample from the Alamo River near Calipatria. This is the third highest concentration found since 1978. Other EDL 95 exceedances were found at Paradise Cut in Region 5; Holtville Main Drain, New River, and Rose Drain in Region 7; and Peters Canyon Channel in Region 8. The EDL 85 was exceeded in Regions 7 and 8. Most of the above areas, especially the Imperial Valley in Region 7, have had high chlorpyrifos levels in the past.

Dacthal

Dacthal or chlorthal-dimethyl is a pre-emergence herbicide for the control of broadleaf weeds and grasses. It has been used on turf, ornamentals, and various crops such as soybeans, beans, cotton, garlic, onions, broccoli, cauliflower, cabbage, and melons (DFA 1980 through 1990). Dacthal is an aromatic carboxylic acid. Its herbicidal activity is the inhibition of cell division. In 1987, the DFA placed dacthal into the reevaluation process because of its environmental persistence and possible adverse effects observed in a rat reproductive study. However, currently dacthal is not listed as a restricted material in California (DFA 1990). The amounts of dacthal registered for use in California increased from

1978 to a peak use in 1982, but leveled off in the 1980's, with the average yearly use from 1983 through 1987 of 410,000 pounds. In 1988, 398,000 pounds were applied primarily for prevention of pests on broccoli, onion, cauliflower, garlic and landscape turf (DFA 1990).

Dacthal was detected in 31% of the samples in Regions 2, 3, 4, 5, 7, and 8 in 1988-89. In past years the frequency of dacthal detection in samples collected statewide generally mirrored the usage of the chemical. From 1982 to 1987, as usage leveled off so did the detection rate of dacthal, remaining relatively constant at about 29%. Region 7 had the highest number of detections in 1988-89 with 62% of the samples containing dacthal. Regions 2 and 4 followed with 38%. The EDL 95 for dacthal was exceeded at six water bodies in Region 7. The highest dacthal level measured in 1988-89 (2,000 ppb) occurred in a 1989 channel catfish sample from Holtville Main Drain in Region 7, which is also the fifth highest level detected to date statewide. The EDL 85 was exceeded in Regions 3, 4, and 7. Samples from all three Regions regularly exceed criteria for dacthal, particularly the Salinas area in Region 3, Calleguas Creek-Revolon Slough area in Region 4, and the Alamo-New River drainages in Region 7.

DDT

DDT and its congeners have been banned in the U.S. since the early 1970's 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 (USEPA 1986b). 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 (USEPA 1986b). The EPA required the reduction of DDT and related impurities in dicofol to less than 0.1% by 1989 (USEPA 1986b). 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.

DDT was detected in 84% of the samples in 1988-89, a frequency similar to past years. DDT was detected in every Region, except Region 1. The average level of p,p' DDE in fish filet samples in 1988-89 (373 ppb) is comparable to the nationwide average. A higher average p,p' DDE level occurred in whole fish samples (1,020 ppb). The whole fish average, like previous years, exceeds the NAS guideline of 1,000 ppb for total DDT. In general, levels of DDT and its metabolites in fish have <u>not</u> shown much of a decline over the years. The FDA action level for DDT was exceeded in a 1989 goldfish sample from the Rio de Santa Clara station in Region 4. This same goldfish sample also represented the highest statewide level of DDT (19,270 ppb) ever recorded in the Program. The NAS guideline was exceeded in samples from Regions 3, 4, 5, 7, and 8. Areas with high DDT levels include: the lower Salinas Valley and the Harkins Slough-Watsonville Slough area in Region 3; Calleguas Creek-Revolon Slough area in Region 4; Paradise Cut and the San Joaquin River in Region 5; the Alamo River and Warren Drain in Region 7; and Peters Canyon Channel and San Diego Creek in Region 8. All these areas have a history of high DDT levels.

Diazinon

Diazinon, an organophosphate insecticide and nematocide, is used extensively for control of household insects, soil insects, and pests of edible crops and other plants (FCH 1989). Currently there are no California restrictions placed on the use of diazinon. However, according to EPA, any product labeled for turf use must now carry a prohibition for use on golf courses and sod farms before it can be sold. In the ten years prior to 1987, statewide use of diazinon was consistent and averaged about 474,000 pounds per year (DFA 1980 through 1988). In 1987 and 1988, over 700,000 pounds of diazinon were registered for use each year (DFA 1989 and 1990). The primary use of diazinon in 1987 and 1988 was for structural pest control and landscape maintenance averaging 59% of the total usage each year. Other applications were made to almonds and other food crops.

Diazinon is rarely detected in the TSMP. From 1978 through 1987 only two samples out of over 500 analyzed contained detectable levels. However, in 1988-89 three samples in three different Regions contained detectable levels of diazinon. Carp from Rose Drain in Region 7 had the highest level of diazinon found to date with 98 ppb. In Region 3, whole threespine stickleback from Harkins Slough upstream from Watsonville Slough contained 63 ppb. The third sample came from the Anza Channel in Region 8 and contained 58 ppb in whole fathead minnow. This is the first time that diazinon has been detected in Region 8.

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 (SWRCB 1988b). The use of dieldrin throughout California has been minimal, decreasing each year, from 166 pounds in 1978 to only 0.2 pounds in 1987, the last year of reported use. Dieldrin is a known carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Dieldrin was detected in 34% of the samples collected statewide in 1988-89 and in all Regions, except Regions 1, 6, and 9. This detection frequency has been fairly consistent for number of years. The highest percentage of samples with detectable levels of dieldrin occurred in Region 7 (62%) and Region 2 (46%). Samples collected in 1988-89 did not exceed the FDA action level for dieldrin. The NAS guideline was exceeded in Regions 3, 7, and 8. The highest 1988-89 level of dieldrin (620 ppb) was found in a 1988 whole sample of threespine stickleback from Harkins Slough upstream from Watsonville Slough in Region 3. The next highest level (580 ppb) also occurred at this station in 1989, again in the same species. The Harkins Slough-Watsonville Slough area along with the Salinas area in Region 3 historically have the highest levels of dieldrin found statewide. Other areas were the NAS guideline was exceeded include: Warren Drain in Region 7 and two samples from Peters Canyon Channel in Region 8. The 140 ppb dieldrin measured in one of the two samples from Peters Canyon Channel is the highest concentration of this chemical found to date in Region 8.

Endosulfan is a broad-spectrum insecticidal chlorohydrocarbon applied primarily to grapes, artichokes, alfalfa, tomatoes, melons, and head lettuce in California. In 1973, the DFA restricted the use of endosulfan in California. Subsequent restrictions have been adopted following the State Board's water quality assessment report recommendations. Endosulfan is extremely toxic to aquatic organisms, adversely affecting growth and development in the parts-per-trillion range (SWRCB 1984). Endosulfan is also acutely toxic to mammals. Endosulfan sulfate, the persistent breakdown product, is more toxic than the parent compound. The average amount of endosulfan applied in California from 1978 to 1986 was 355,000 pounds (DFA 1980 through 1988). In 1987, 445,000 pounds were applied while 431,000 pounds of endosulfan were applied in 1988 (DFA 1989 and 1990).

Endosulfan was detected in 27% of the samples statewide in Regions 1, 3, 4, 5, 7, and 8. The detection frequency was twice as high in 1988 as it was in 1989 (37% versus 16%). Prior to 1988, endosulfan was detected in about 14% of the samples. The Regions with the highest frequency of detection in 1988-89 were Region 7 (48%) and Region 3 (47%). Only one sample in Region 1 had a detectable level of endosulfan. Almost 19% of the samples collected in 1988-89 exceeded the NAS guideline in Regions 3, 4, 5, 7, and 8. The highest level detected (687 ppb) was in a 1988 threespine stickleback sample collected from Espinosa Slough in Region 3. This concentration was also the fourth highest found to date in the Program. Many of the other concentrations in 1988-89 were also among the highest levels measured. Of the top 20 endosulfan concentrations detected since 1978, 50% of them were found in 1988 in Regions 3, 5, 7 and 8. Areas where high levels of endosulfan were found include: the Salinas and Watsonville areas of Region 3; Calleguas Creek area of Region 4; the Colusa Drain and San Joaquin River area of Region 5; Imperial Valley in Region 7; and Peters Canyon Channel and San Diego Creek in Region 8. The 143 ppb endosulfan detected in 1989 at Peters Canyon Channel is the highest concentration yet found in Region 8. Of the areas mentioned above, only the Salinas area has a history of high endosulfan levels.

Endrin

Endrin is an insecticidal chlorohydrocarbon used alone or in combination with other insecticides for the control of insects on cotton, broccoli, cabbage, vegetable seed 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. Endrin is listed as a restricted material in California and only one product, a bird repellant, is registered with EPA and California (SWRCB 1988b). The mammalian toxicity of endrin is the highest of the cyclodiene insecticides such as aldrin, dieldrin, endosulfan, heptachlor, and chlordane (USEPA 1980a). Despite endrin's high toxicity, the parent compound is metabolized and excreted more readily than other organochlorine insecticides (USEPA 1980a). Toxic metabolites such as 12-ketoendrin may persist, however. Limited use and rapid depuration may explain the infrequency of detection of endrin by the TSMP. Statewide, the average yearly use of endrin prior to 1986 was 560 pounds. The amount used decreased each year until by 1986 there was zero usage (DFA 1980 through 1990).

Endrin was detected in five samples from Regions 3 and 4 in 1988-89. Only about 3% of the samples from 1978 to 1987 contained detectable levels of endrin. The highest concentration found in 1988-89 (30 ppb) was in two whole samples of threespine stickleback from Espinosa Slough and Salinas Reclamation Canal in Region 3. This concentration is well below the FDA and NAS criteria. Endrin was also detected in Harkins Slough upstream from Watsonville Slough in Region 3 and in the Rio de Santa Clara in Region 4. Endrin was first detected in Region 4 in 1987.

Heptachlor and Heptachlor Epoxide

Heptachlor, a chlorinated cyclodiene insecticide, was used to control soil insects on food crops until the mid-1970's. Subsequent use was then reduced and limited to structural pest control, landscape maintenance, and rights of way. Heptachlor is a known carcinogen, causing liver tumors in test organisms (USEPA 1980b) 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 (USEPA 1980b). 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 (SWRCB 1988b). The average use of heptachlor per year prior to 1986 was 30,000 pounds (DFA 1980 through 1987). In 1987, 83,000 pounds were registered for use followed by only 3,000 pounds in 1988.

Heptachlor, the parent compound, was not detected in any samples collected in 1988-89. Previously, heptachlor, had been detected only once by the TSMP in a 1980 sample from the Alamo River in Region 7. Heptachlor epoxide, the primary metabolite, was detected in three samples all from Region 3. Prior to 1988, heptachlor epoxide had been detected in 4% of the samples from Regions 2, 3, 4, 5, and 8. Of the three 1988-89 samples, the highest level found was 14 ppb in a whole threespine stickleback sample from Harkins Slough. All three of the samples were well below the FDA and NAS criteria. In previous years, Region 3 has had the highest incidence of heptachlor epoxide detection, primarily in the lower Salinas Valley and Watsonville areas.

Hexachlorobenzene (HCB)

HCB, a wheat seed protectant, is no longer registered in California because of its high soil persistence. Commercial production of HCB in the United States was discontinued in 1976. No uses have been reported to the DFA for the last ten report years (DFA 1980 through 1990). HCB may be present as impurities in other pesticides such as dacthal or pentachloronitrobenzene (SWRCB 1988c). While this compound is only slightly acutely toxic to mammals, it is a known carcinogen (USEPA 1980c) and is listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act as both a carcinogen and a reproductive toxicant. The EPA has concluded that hexachlorobenzene has a high potential for bioconcentration in biota. Little is known of the acute aquatic toxicity of HCB (USEPA 1980c).

HCB was found statewide in 18% of the samples from Regions 2, 3, 4, 5, 7, and 8 in 1988-89. This detection frequency is only slightly higher than previous years. The highest level found in 1988-89 was 53 ppb in a 1989 white catfish sample from Lake Chabot in Region 2. This concentration is also the highest detected to date in Region 2. However, Region 7 was the area with the highest incidence of HCB detection (33%) as well as some of the highest levels overall for HCB, specifically, samples from the New River. Samples from the New River have had high levels of HCB since 1980. The EDL 95 was exceeded at Lake Chabot in Region 2, Rio de Santa Clara in Region 4, and the New River. Samples exceeding the EDL 85 were found in Regions 2, 4, 5, 7, and 8. The 9.6 ppb HCB detected in Region 4 and the 10 ppb detected in Region 8 are also regionwide highs.

Hexachlorocyclohexane (HCH) or Lindane

Four isomers of HCH (alpha-, beta-, delta-, and gamma-) are monitored by the TSMP. Gamma-HCH is also known as lindane and is the only isomer with a known use. The development of lindane was preceded by the use of a technical grade HCH, known as BHC, which was a mixture of five steroisomers. The production of lindane and the cancellation of BHC, also used as a pesticide, resulted from the discovery that the insecticidal activity of BHC was attributed solely to the gamma-isomer. Lindane degradation by soil microorganisms is slow. Lindane is capable of isomerization to alpha- and delta- forms by microorganisms and plants. The EPA has concluded that lindane is a human carcinogen (USEPA 1985a). HCH was added to the State's list of chemicals known to cause cancer in compliance with the Safe Drinking Water and Toxic Enforcement Act of 1986.

Lindane is a multi-purpose insecticide and acaricidal chlorinated hydrocarbon used against pests of vegetable seeds, forest products, livestock, and cotton (USEPA 1985a). In California, lindane is used primarily for structural and residential pest control. Other uses include landscape maintenance and protection of cotton. Lindane is currently classified as a California restricted use material which requires licenced private and commercial applicators to obtain permits for application on agricultural commodities. Statewide usage of lindane has fluctuated over the years with an average use of about 38,383 pounds between 1978 and 1987 (DFA 1980 to 1989). In 1987 and 1988, 23,000 and 31,000 pounds were applied, respectively, primarily for structural pest control and cotton in California (DFA 1989 and 1990).

Total HCH was detected in 16% of the samples in 1988-89 from all Regions, except Regions 3 and 9. This detection frequency is similar to past years. Lindane was detected in 15% of the samples and alpha HCH was detected in 9% of the samples (same regions as total HCH). Lindane was detected for the first time in Region 1 in the Russian River and in Mark West Creek. The beta- and delta- isomers of HCH were not detected in any of the samples collected in 1988-89. No sample exceeded the NAS guideline for total HCH and lindane. Prior to 1988, total HCH had exceeded the NAS guideline in five samples from Regions 4 and 7. The highest lindane level in 1988-89 was 15 ppb in a 1989 carp sample from Prado Lake in Region 8. Two red shiner samples from Peters Canyon Channel in 1989 contained the two highest levels of alpha-HCH (8.3 and 8.1 ppb) detected statewide.

Methoxychlor

According to the 1989 Farm Chemical Handbook (FCH 1989), methoxychlor is used extensively as an agricultural, structural, home, and garden insecticide. There are presently no California or EPA use restrictions on methoxychlor (SWRCB 1988c). There are few acute and chronic aquatic toxicity data for methoxychlor (USEPA 1986c). However, the EPA reports a low accumulation rate and low toxicities for birds and mammals. The statewide use of methoxychlor, primarily for alfalfa crops and other agricultural uses, has been on a general decline since 1980 (DFA 1982 through 1988). In 1987, 837 pounds were used and, in 1988, only 562 pounds were registered, primarily for alfalfa and landscape and industrial area maintenance (DFA 1989 and 1990).

Methoxychlor was detected for the first time by the TSMP in 1987. It appeared at one station on the Salinas Reclamation Canal in Region 3 and at three stations on San Diego Creek in Region 8. Residues in tissue ranged from 17 to 28 ppb. In 1988-89, there were four detections of methoxychlor. In 1988, methoxychlor was detected twice in carp samples from Rose Drain (16 ppb) and the Alamo River (15 ppb), both in Region 7. In 1989, a goldfish sample from the Rio de Santa Clara in Region 4 and a channel catfish sample from the Holtville Main Drain in Region 7 contained the highest level found to date (44 ppb).

Oxadiazon

Oxadiazon is a contact herbicide with pre- and early post-emergence activity on both grasses and broad-leaved species (FCH 1989). The recommended use is as a selective preemergent herbicide for control of annual grasses and broadleaf weeds in turf, ornamentals, and flowers. The registered use of oxadiazon in California has increased consistently from 600 pounds used in 1979 to 11,000 pounds in 1988. In 1987 and 1988, oxadiazon was primarily applied for landscape maintenance, rights of way, structural pest control, ornamentals, turf, and roses. Oxadiazon is reportedly toxic to fish and bees (FCH 1989). Currently there are no California restrictions on oxadiazon.

The TSMP first identified oxadiazon in 1988. In 1988-89, oxadiazon was detected in nine samples collected in Regions 2, 4, 8, and 9. Region 8 had the highest incidence of detection at 63% (5 out of 8 samples), including the three highest levels of oxadiazon found to date. All three samples were whole body red shiner samples from Peters Canyon Channel and San Diego Creek. The highest level detected was 2,200 ppb at the Peters Canyon Channel Station in 1989. The second highest was 1,800 ppb at San Diego Creek, also in 1989. Another sample from Peters Canyon Channel in 1989 contained the third highest level with 960 ppb. Other areas where oxadiazon was found include: Coyote Creek and Lake Chabot in Region 2, Harbor Park Lake in Region 4, Anza Channel in Region 8, and Guajome Lake in Region 9.

Parathion - Ethyl and Methyl

Ethyl and methyl parathion are organophosphate insecticides. Ethyl parathion is used primarily in California on almonds, prunes, peaches, nectarines, plums, oranges, and head lettuce. Methyl parathion is used primarily on rice, alfalfa, tomatoes, lettuce, cotton, artichokes, and sugarbeets. Ethyl and methyl parathion application in California requires a certified applicator when used on agricultural commodities. Both are considered acutely toxic to aquatic organisms. The statewide use of ethyl parathion fluctuated between 1978 and 1986 with an average yearly use of 738,000 pounds (DFA 1980 through 1988). In 1987, 786,000 pounds were used statewide while 1,100,000 pounds were used in 1988, primarily for almonds (DFA 1989 and 1990). The average yearly use of methyl parathion has decreased from a high of 413,000 pounds in 1978 to a low of 153,000 pounds in 1988 (DFA 1980 through 1990). Approximately half the yearly use of methyl parathion was applied to rice and alfalfa. Methyl parathion is also used for public health and structural pest control.

In 1988-89, ethyl parathion was detected in a total of 6 sample from Regions 2, 3, 4, and 7. From 1978 to 1987, ethyl parathion had only been detected in four samples collected in 1985 and one sample collected in 1986, all from Region 7. The highest concentration detected in 1988-89 (38 ppb) was found in a 1988 carp sample from Rose Drain in Region 7. Other areas were ethyl parathion was found include: Calabazas Creek in Region 2, Harkins Slough in Region 3, Harbor Park Lake in Region 4, and the Alamo River in Region 7.

Methyl parathion was detected for the first time in the TSMP in 1988. It was not detected in 1989. Samples from three water bodies contained detectable levels in 1988: goldfish from Harbor Park Lake contained 13 ppb, channel catfish from New York Slough in Region 2 contained 11 ppb, and suckers from Willow Creek in Region 5 contained 10 ppb. All three concentrations are at or near the detection limit of 10 ppb.

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 listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

The TSMP measures three congeners of PCB: 1248, 1254, and 1260. Prior to 1988, total PCBs were detected in 28% of the samples from all Regions, except Regions 1 and 6. In the last two years, 23% of the samples contained detectable levels of PCB's found in Regions 2, 3, 4, 5, and 8. The highest rate of detection of total PCBs occurred in Region 2 (69%) and Region 8 (57%). The most stable congener, PCB 1260, accounted for most of the detectable PCBs (20%) in 1988-89 samples. PCBs did not exceed the FDA tolerance level of 2,000 ppb in 1988-89. However, the NAS guideline was exceeded in three samples from Regions 2, 4, and 8. In Region 8, whole fathead minnow collected from Anza Channel in 1989 exceeded the guideline with 890 ppb, which was also the highest level found in 1988-89. This concentration is the highest PCB level yet detected in Region 8. In Region 4, goldfish collected from

Harbor Park Lake in 1989 exceeded the guideline with 820 ppb. A 1989 largemouth bass sample from Vasona Lake in Region 2 contained 680 ppb. PCBs last exceeded the guideline in Region 2 at Coyote Creek in 1981 and 1983 goldfish samples.

Pentachlorophenol (PCP) and Tetrachlorophenol (TCP)

PCP and TCP are not part of the normal TSMP chemical scan. From 1978 to 1987 a total of 14 samples from nine stations in Regions 1 and 8 have been analyzed for PCP and TCP. PCP is used primarily as a fungicide and bactericide in the treatment of wood products. Other uses for PCP include application for structural pest control, landscape maintenance, and along rights-of-way. The registered use of PCP has been relatively low in California, with a yearly average of about 3,400 pounds from 1978 through 1986. In 1987 and 1988, 4,450 pounds and 5,235 pounds, respectively, were registered for statewide use. The manufacture of TCP has been discontinued. The EPA restricted the application of PCP to non-home use. In addition, the EPA required the registrants to reduce levels of approximately 10 contaminants in PCP products. Registrants were required to limit the dioxin contaminant to 1 ppm (USEPA 1986d). This contaminant causes tumors in rats and mice (USEPA 1986d). PCP is listed by the State as a known carcinogen pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Region 1 was the only region to request PCP and TCP analyze in 1988-89. Samples from five stations were analyzed (Table 13). Only a 1988 whole rainbow trout sample from Beaughton Creek contained a detectable level of PCP. TCP was not detected in any of the five samples. The 3.9 ppb PCP detected in 1988 is the fifth time PCP has been found in Region 1.

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 (SWRCB 1982). 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 (SWRCB 1988b). There has been a substantial decrease in use of toxaphene, especially to food crops, evidenced by 1,000,000 pounds registered in 1978 to 647 pounds registered in 1987 and zero pounds registered in 1988 (DFA 1980 through 1990). In 1987, 96% of the toxaphene registered was applied to cotton and alfalfa.

Toxaphene was detected in 16% of the samples in 1988-89. This detection frequency is less than the statewide average of 22% from 1978 through 1987. Toxaphene was detected in all Regions, except Regions 1, 2, 6, and 9 with no one region dominating in frequency of detection. The highest level of toxaphene detected in 1988-89 (6,800 ppb) was found in a 1989 goldfish sample from the Rio de Santa Clara in Region 4. This was the only sample to exceed the FDA action level for toxaphene.

The 6,800 ppb was also the fifth highest tissue level recorded since 1978 and also the highest level yet detected in Region 4. The NAS guideline for toxaphene was exceeded in 21 samples from Regions 3, 4, 5, 7, and 8. Both the detection limit and the NAS guideline for toxaphene is 100 ppb, so all samples with detectable levels of toxaphene will exceed the guideline. Areas where toxaphene was detected include: the Salinas-Watsonville area in Region 3, Calleguas Creek-Revolon Slough area in Region 4, Paradise Cut and the San Joaquin River in Region 5, the Imperial Valley in Region 7, and Peters Canyon Channel and San Diego Creek in Region 8. Toxaphene is regularly detected in all these areas.

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 (NAS 1973). Included in this group of pesticides, termed Chemical Group A, are aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene.

In 1988-89, Chemical Group A, with two exceptions, exceeded the guideline when at least one of the group exceeded the individual guideline. The first exception was a 1989 whole red shiner from Coyote Creek in Region 2. This sample had a Chemical Group A total of 116 ppb. Chlordane made up most of this total with 99 ppb, nearly exceeding the individual guideline. Dieldrin and HCH were also detected in this sample bringing the total over 100 ppb. The second exception was also from Region 2 in 1989. White catfish from Lake Chabot contained a Group total of 101 ppb. Chlordane also made up most of this total with 87 ppb. Like the Coyote Creek sample, dieldrin and HCH were also detected in small amounts. Chemical Group A has not been useful in identifying additional problems not already uncovered by assessment of individual pesticides in the group. Including the two 1989 samples from Region 2, only four samples have exceeded the group guideline without exceeding the individual guideline.

Arsenic

Arsenic is a concern as a surface water pollutant because of its human carcinogenicity, persistence in the environment, and potential for bioaccumulation in aquatic organisms (SWRCB 1984). Arsenic is listed as a known carcinogen by the State pursuant to the Safe Drinking Water and Toxic Enforcement Act of 1986. Arsenic may reach surface waters from natural sources of this trace element or by agricultural application of arsenical pesticides. Investigation by the State Board of arsenic levels in the San Joaquin Valley concluded that use of arsenical pesticides may increase the concentrations in drainage waters and sediments (SWRCB 1984). In 1988, the total combined arsenical pesticide usage statewide was 152,000 pounds (DFA 1990). Between 1981 and 1988, the average yearly application of all arsenic-based compounds combined was 164,000 pounds (DFA 1983 through 1989). Sodium arsenite, cacodylic acid, and monosodium methanearsonate (MSMA) were the most predominantly used arsenic-based pesticides in recent years. In 1988, these three pesticides represented 99.9% of the arsenic-based pesticides registered for use in California (DFA 1990). Sodium arsenite was applied solely to grapes. Cacodylic acid and MSMA were used primarily for cotton, rights of way, oranges, landscape maintenance, and several other non-agricultural purposes. Another arsenic-based pesticide, disodium methanearsonate (DSMA), was used relatively extensively in the early 1980s, but usage has decreased to just over 182 pounds in 1988. In California, DSMA is used mainly for cotton and landscape maintenance (DFA 1980 through 1990). Other arsenic-based pesticides still used in very small amounts in 1988 (i.e. less than 2 pounds) include arsenic pentoxide and arsenic trioxide. Several arsenic-based pesticides, such as lead arsenate, used before in California are no longer registered with DFA.

Arsenic was detected in 63% of the samples collected in 1988-89. This frequency is lower than the past three year average detection of 79%. Starting in 1985, the analytical method used to detect arsenic was improved resulting in better recovery and the lower detection limit of 0.05 ppm. Following the change in method, the number of samples with detectable levels of arsenic increased from 52% from 1978 to 1984 to 79% from 1985 to 1987. On a regional basis, Region 1 had the highest rate of detection in 1988-89 with 82% followed by Region 9 with 73%, Region 3 with 72%, and Region 2 with 69%. Statewide, 11 out of 95 samples containing detectable levels of arsenic exceeded the EDL 95 criteria with 17 samples exceeding the EDL 85. The EDL 95 was exceeded at Suisun Bay in Region 2; Monterey Harbor and Goleta Slough West in Region 3; Mugu Lagoon in Region 4; and San Dieguito Lagoon and Tijuana Estuary in Region 9. Prior to 1988, high levels of arsenic were found in many of the same water bodies. The two highest levels of arsenic found to date, 29.0 and 16.0 ppm, were detected in 1988 and 1989 samples of grey smoothhound shark from Mugu Lagoon in Region 4. A 1988 diamond turbot sample from San Dieguito Lagoon, a 1988 striped bass sample from Suisun Bay, and a 1989 blue rockfish sample from Monterey Harbor contained the highest levels of arsenic (9.6, 1.8, and 1.5 ppm, respectively) found in each Region. The 9.6 ppm was also the third highest level yet detected. The EDL 85 exceedances were found in Regions 1, 2, 3, 5, and 9.

Cadmium

Cadmium is one of the most toxic trace elements analyzed by the TSMP. Cadmium may be elevated in surface water due to fallout from air pollution, industrial discharge, or municipal effluent (USEPA 1985b). 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 (USEPA 1985b). Furthermore, the TSMP has detected higher cadmium levels in rainbow trout and largemouth bass, suggesting that these species may accumulate higher levels in the liver or by the nature of their level in the food chain they may be exposed to more cadmium. These factors indicate the difficulty in determining the exposure and impact of cadmium on aquatic organisms and their predators. Cadmium is a known human carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Cadmium was detected in 79% of the samples in 1988-89. In years prior to 1988, cadmium was detected in nearly all of the samples analyzed (94%). Samples from all nine Regions contained detectable levels of cadmium. On a regional basis, the highest rates of detection were found in Region 5 (22 out of 22 samples), Region 4 (8 out of 9 samples), Region 6 (16 out of 18 samples), and Region 3 (15 out of 17 samples). The EDL 95 was exceeded at only two stations: Mugu Lagoon in Region 4 and the Sacramento River near Keswick in Region 5. The highest level of cadmium found in 1988-89 was 5.5 ppm in a 1988 grey smoothhound shark sample from Mugu Lagoon. This concentration is the highest cadmium level found in Region 4 and is also the third highest cadmium concentration since 1978. In 1989, the sample from Mugu Lagoon contained 3.2 ppm cadmium. The EDL 85 was exceeded in Regions 2, 3, 4, 5, 6, 8, and 9. The 1.0 ppm cadmium found in a 1989 white sturgeon sample from Suisun Bay in Region 2, the 0.54 ppm in a 1989 brown trout sample from Pine Creek in Region 6, and the 0.5 ppm found in a 1989 channel catfish sample from Oso Reservoir in Region 9 are the highest concentrations found in each regions. Prior to 1988, Lake San Antonio in Region 3 and the Keswick station on the Sacramento River were identified as having the highest cadmium levels in the State.

Chromium

Elevated chromium concentrations have been detected by the TSMP in watersheds where probable sources of chromium are mine drainage, agricultural runoff, and industrial discharge (SWRCB 1986). Chromium-enriched water from acid mine waste has increased chromium concentrations in both the Sacramento River and the San Joaquin River. Agricultural runoff may contain chromium-based fungicides which have been used to preserve wood and to control diseases of turf (FCH 1989). Industrial uses of hexavalent chromium salts include metal plating, aluminum anodizing, leather tanning, and the manufacture of paints, explosives, ceramics, and paper. The textile, ceramic, glass, and photographic industries utilize trivalent chromium in their processing. The bioavailability and toxicity of chromium depends on the metal's oxidation state, pH, hardness, and salinity. The toxicity of chromium to fish species is variable. Salmonid species are 100 times more sensitive than carp, bluegill, and fathead minnows (USEPA 1984). Because chromium is accumulated in gills, liver and kidney rather than muscle, fish usually die before accumulating toxic levels of chromium in edible tissue (Jaworski 1985). Therefore, the potential for biomagnification is low. Hexavalent chromium is a mammalian carcinogen listed by the state pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

In 1988-89, chromium was detected in 31% of the samples from all Regions, except Region 7. This is about the same level of detection that occurred from 1978 through 1987. Region 1 had the highest rate of detection with 59% of its samples containing chromium followed by Region 2 with 46%. Chromium was detected in Region 6 at a much higher frequency (22%) than was found in past years (3%). The EDL 95 was exceeded in Regions 1, 2, 5, and 8. Areas with high chromium levels include: Hardscrabble, Indian, and Big Sulfur Creeks in Region 1; Coyote Creek in Region 2; the Sacramento River near Keswick in Region 5; and Anza Channel in Region 8. In previous years, the EDL 95 was exceeded in some of the same areas of the State including Hardscrabble Creek, Coyote Creek, and the Sacramento River. The highest concentration of chromium (0.73 ppm) occurred in a 1989 whole red shiner sample from Coyote Creek. This red shiner sample was also the highest fish tissue level found statewide since 1978. The previous high fish concentration was 0.71 ppm in a 1987 whole fathead minnow sample from the same station. Invertebrates contain the highest chromium concentrations found in the Program ranging up to 2.1 ppm. The 0.38 ppm chromium found in a 1989 whole fathead minnow sample from Anza Channel is the highest concentration detected in Region 8. The EDL 85 was exceeded in Regions 1, 2, 3, 4, 5, 6, and 9.

Copper

Copper in aquatic biota is widespread throughout the state. Elevated copper concentrations may result from industrial effluent, algal control efforts, or mine runoff. Metallic copper or copper salts are used in alloy manufacture, the electrical industry, textile processes, pigmentation, tanning, photography, engraving, and electroplating. Copper is also a component of certain insecticides and fungicides. During 1988-89, 3,400,000 pounds of copper based insecticides and fungicides were used in California. Copper sulfate, copper hydroxide, copper, and copper oxychloride sulfate were used in the highest amounts, primarily for nut and fruit crops, and landscape maintenance. Mine wastes have been implicated as the source of elevated copper in the upper Sacramento River. Elevated copper in surface waters is a potential pollution hazard to aquatic organisms. Copper does not appear to bioconcentrate in the edible tissue of freshwater organisms to any significant degree. This low bioconcentration factor and the relatively low mammalian toxicity reduces the potential human health risk from ingestion of freshwater fish (USEPA 1980d).

Typically, copper was detected in all of the samples analyzed in 1988-89. The EDL 95 was exceeded in nine samples from Regions 1, 2, 3, 4, 5, 8 and. 9. High copper levels were found at McDaniel Slough in Region 1, Suisun Bay in Region 2, Carmel Lagoon in Region 3, the San Gabriel River in Region 4, the Sacramento River near Keswick and Central Drain in Region 5, Big Bear Lake in Region 8, and San Dieguito Lagoon in Region 9. The highest copper level in 1988-89 (300 ppm) was found in a 1989 rainbow trout sample from the Sacramento River near Keswick. This concentration was the sixth highest overall and the third highest for rainbow trout since 1978. A 1988 sample of brown trout from the East Walker River in Region 6 contained 230 ppm copper which is the highest concentration found to date in that Region. Copper is a metal whose uptake and accumulation seems to be more species dependent than other metals. Trout are known to accumulate copper in the liver to a much higher level than other species. Because of this, trout are treated separately in the TSMP and ranked only against other trout when calculating the EDLs for copper. Like trout, white bass seem also to accumulate copper to high levels. The highest level of copper found in non-trout, non-white bass samples (110 ppm) occurred in a 1988 striped bass sample from Suisun Bay in Region 2. The EDL 85 was exceeded in Regions 1, 4, 5, 6, 8, and 9.

Lead

Lead is moderately toxic to aquatic organisms. Lead is a known reproductive toxicant in humans and two lead salts, lead acetate and lead phosphate, are human carcinogens. Lead is listed as a reproductive toxicant by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act. Urban runoff and industrial effluents can contribute to lead loading. A variety of lead salts are used extensively in industry, although the largest source contributing to surface water runoff in urban areas is thought to come from leaded gasoline (USEPA 1980e).

Lead was detected in 11% of the samples in 1988-89. In recent years, the frequency of detection has decreased. From 1978 to 1983, about 40% of the samples contained detectable levels of lead. This rate decreased to 19% from 1984 to 1987. The widespread use of unleaded gasoline is thought to be the main reason why lead is not detected as frequently. Lead was detected in all Regions, except for Regions 1 and 5. The Region with the highest frequency of detection was Region 2 with 38%. The EDL 95 was exceeded at only one station, Coyote Creek in Region 2. The 1989 whole red shiner sample collected at this station tied the highest statewide concentration of lead found in the Program (1.1 ppm). In 1986, a whole threespine stickleback sample from San Leandro Creek in Region 2 also contained 1.1 ppm lead. The EDL 85 was exceeded in Regions 2, 3, 4, 7, and 8. The areas exceeding the EDL 85 include: Suisun Bay in Region 2, Goleta Slough in Region 3, the San Gabriel River in Region 4, the New River in Region 7, and Anza Channel in Region 8. Elevated levels of lead were previously found in the San Gabriel River in 1983 and 1985. The other areas mentioned above have no history of elevated lead levels.

Mercury

Mercury is the most toxic of the trace elements analyzed by the TSMP. It is acutely toxic to aquatic organisms at levels less than 3 ppb (USEPA 1986c). Mercury bioaccumulates in fish to levels that are hazardous to human health. Previous monitoring by the TSMP has found levels above the FDA action level of 1.0 ppm in water bodies of central California and along the north coast. Possible sources of mercury are the naturally occurring cinnabar deposits and related mining activities in the coast range, and past gold mining activities in the Sierra foothills.

As is usually the case, mercury was detected in nearly all samples (98%) analyzed in 1988-89. More samples were analyzed for mercury than for any other substance. The FDA action level for mercury was exceeded in three samples from Region 2. In 1988, rainbow trout and sucker from Alamitos Creek downstream of Almaden Reservoir contained 1.55 and 1.33 ppm mercury, respectively. Goldfish from Almaden Reservoir sampled in 1989 contained 1.5 ppm mercury, which was the highest concentration measured in 1988-89. Eight samples from Regions 1, 4, 5, and 7 exceeded the MIS for mercury of 0.5 ppm. The MIS exceedances occurred at Lake Pillsbury, Lake Sonoma, and Lake Mendocino in Region 1; Mugu Lagoon in Region 4; Bullards Bar Reservoir in Region 5; and the New River near the International Boundary in Region 7. Samples from the Alamitos Creek station exceeded the FDA action level in 1986 and Lake Pillsbury exceeded the MIS in 1981.

Nickel

Nickel can enter surface waters from natural sources, mine runoff, or municipal and industrial effluents. Elevated concentrations of nickel have been reported by the TSMP in the northern coastal range. Natural nickel deposits are not readily bioavailable because of nickel's low solubility in water. However, nickel may be mobilized by acidification from acid mine waste. Urban or industrial sources of nickel include electroplating processes, fossil-fuel refining, and heavy fuel oil combustion. Nickel has a relatively low aquatic toxicity compared to the other trace elements monitored by the TSMP. Nickel, however, is a known human carcinogen listed by the State pursuant to the 1986 Safe Drinking Water and Toxic Enforcement Act.

Nickel was detected in 21% of the samples in 1988-89 in all Regions, except Regions 7 and 9. From 1978 to 1987, nickel was detected in 24% of the samples analyzed. The region with the highest frequency of detection was Region 1 with 47%. The EDL 95 was exceeded at Smith River, Hardscrabble Creek, and Indian Creek in Region 1; Coyote Creek and Suisun Bay in Region 2; Malibu Creek and the San Gabriel River in Region 4; and Pine Creek and Grass Valley Lake in Region 6. All three Region 1 stations, Suisun Bay, and the San Gabriel River have a history of elevated nickel levels. The highest nickel concentrations detected in 1988-89 were 1.2 ppm in white sturgeon from Suisun Bay and 1.1 ppm in mozambique mouthbrooder from the San Gabriel River. The 1.2 ppm concentration is the highest nickel level detected in Region 2. Brown trout from Pine Creek and bullhead from Grass Valley Lake contained 0.5 ppm nickel, which is the first time nickel had been detected in Region 6. The EDL 85 was exceeded in Regions 1, 3, 5, and 8.

Selenium

Toxicity of selenium to aquatic organisms and their predators has been a statewide concern since it was identified as the element responsible for embryonic abnormalities in birds from Kesterson National Wildlife Refuge. Subsequent investigation by the TSMP indicated elevated selenium levels in agricultural drains and the Salton Sea in Region 7. The DHS has issued fish consumption health advisories for both the Grassland area surrounding Kesterson and the Salton Sea. Selenium is an essential mineral. Its toxicity is affected by its oxidation state. The two main sources of selenium in nature are coal deposits and marine shales. Identified sources of selenium pollution include effluents from oil refineries and concentration of seleniferous soils via agricultural practices. At elevated levels, selenium can become toxic to fish, with symptoms including, among others, reproductive failure and death (Lemly and Smith 1987; Bainbridge et al. 1990).

Selenium was detected in nearly all (97%) of the samples for which it was analyzed. Selenium is typically found in most samples. The MIS for selenium (2.0 ppm) was exceeded in a 1989 largemouth bass sample from Bear Gulch Reservoir in Region 2 and at five stations in Region 7. The Region 7 stations are the Salton Sea, Rose Drain, Verde Drain, Wiest Lake, and the Colorado River upstream of the Imperial Dam. The highest level of selenium found in 1988-89 (2.7 ppm) was found in a 1989 bairdiella sample from the south Salton Sea. The remaining four samples from Region 7 ranged in concentration from 2.2 to 2.5 ppm. The 2.0 ppm found at Bear Gulch Reservoir is the first time selenium equaled or exceeded the MIS in Region 2.

Silver

Silver is highly toxic to aquatic organisms, ranking as one of the most toxic of the trace elements analyzed by the TSMP. Elevated silver levels in California are associated with heavy industry or mining activities. Metallic silver is used in alloys, electroplating, food processing, and the beverage industry. Silver nitrate is used in photography, the ceramics industry, and electroplating. In 1987, a change in TSMP instrumentation increased the sensitivity for the detection of silver, thereby reducing the detection limit from 0.02 to 0.01 ppm. As a result of this change in instrumentation, the detection frequency increased by nearly 20% from 1986 to 1987.

In 1988-89, silver was detected in 44% of the samples collected statewide. This is a decrease in detection frequency from 51% in 1987. Samples from all nine Regions had detectable levels of silver. The highest rate of detection occurred in Region 6 with 72%. Only one sample in Region 7, the New River near the International Boundary, contained silver above the detection limit. The EDL 95 was exceeded at McDaniel Slough in Region 1; Suisun Bay in Region 2; Mugu Lagoon and the San Gabriel River in Region 4; Courtright Reservoir, Huntington Lake, and Wishon Reservoir in Region 5; and Martis Creek, Owens River Gorge, and Pine Creek in Region 6. Of these stations, only the San Gabriel River has a history of high silver levels. The highest silver concentration found in 1988-89 (5.4 ppm) was detected in a mozambique mouthbrooder sample from the San Gabriel River. This concentration was also the highest silver level yet measured in the Program. The previous statewide high was 4.1 ppm in a 1985 tilapia sample from the same station. The 3.6 ppm silver in a 1989 brown trout sample from Courtright Reservoir in Region 5 and the 1.3 ppm in a brown trout sample from Martis Creek in Region 6 are regionwide highs. The EDL 85 was exceeded in Regions 1, 2, 3, 4, and 6.

Zinc

Zinc is an essential trace mineral and, at high doses, it is acutely toxic to freshwater species. The toxicity and bioavailability of zinc depends on physical and chemical characteristics such as pH, salinity, temperature, and turbidity. Elevated zinc concentrations in surface waters have been associated with mine runoff and industrial effluent. Zinc has many uses, including electroplating and alloy manufacturing, and is a component of many products such as cosmetics, pharmaceutics, dyes, paint, and insecticides.

Typically, zinc was detected in all samples analyzed in 1988-89. The EDL 95 was exceeded at Big Lagoon in Region 1, Suisun Bay in Region 2, Moss Landing Harbor and Monterey Harbor in Region 3, Eagle Lake in Region 6, and Anza Channel in Region 8. Only Suisun Bay has a history of high zinc levels. The highest level of zinc found in 1988-89 (63 ppm) was detected in a 1989 white sturgeon sample from Suisun Bay. This concentration is the highest level of zinc in fish found to date statewide. Two higher values were found in 1980 crayfish samples from the Colorado River (Region 7) and the San Diego River (Region 9). The 50 ppm zinc in a 1989 sculpin sample from Big Lagoon in Region 1 and the 42 ppm in a 1989 whole sample of fathead minnow from Anza Channel in Region 8 are the highest concentrations detected to date in each region. The EDL 85 was exceeded in Regions 1, 3, 4, 8, and 9.

APPENDIX I

Toxic Substances Monitoring Program

Summary of 1988-89 Data: Organic Chemicals in 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)	Dieldrin (N/F)
205.30.08	Coyote Cr/Brokaw Rd	PRS	W	07/11/89					
205.40.01	Vasona Lake	LMB	F	07/13/89					
206.50.03	Lake Chabot	WCF	F	11/21/89					
305.10.04	Harkins Sl/u/s Watsonville Sl	STB	W	07/28/88				3799.0#	620.0#
305.10.04	Harkins Sl/u/s Watsonville Sl	STB	W	07/28/88				3528.0#	580.0#
305.10.07	Watsonville Sl/Lee Rd	SBF	F	07/28/88					
306.00.06	Elkhorn Slough	YFG	F	07/27/88					
309.10.06	Salinas Rec Cl/u/s Tembladero Sl	STB	W	07/26/88			220.0*	1128.0#	220.0#
309.10.08	Espinosa Slough	STB	W	07/26/88				1112.0#	140.0#
309.10.10	Alisal Slough/West Salinas	STB	W	07/25/88				2349.0#	

STATION NUMBER	Total Endosulfan (N/F)	alpha-HCH (EDL)	Hexa-chloro-benzene (N)	Oxadiazon (N/F)	Total PCB (N/F)	Toxaphene (N/F)	Chemical Group A (N)
205.30.08			9.7*				116.1#
205.40.01					680.0#		
206.50.03			53.0**	220.0**			
305.10.04	412.0#					930.0#	2061.6#
305.10.04	372.0#					820.0#	1858.4#
305.10.07	199.0#						216.0#
306.00.06	110.0#						110.0#
309.10.06	328.4#					790.0#	1416.6#
309.10.08	687.6#					400.0#	1296.9#
309.10.10	130.0#					300.0#	516.4#

* = 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.

TOXIC SUBSTANCES MONITORING PROGRAM

1991 DATA REPORT

93-1WQ
1993

Prepared by
Del Rasmussen
Division of Water Quality

Field and Laboratory Operations Conducted by the
Water Pollution Control Laboratory
California Department of Fish and Game

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

APPENDIX O (continued)
Toxic Substances Monitoring Program
Station Sampling History

Station Name	Station Number	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
		SAMPLE YEAR *													
Old Salinas River/Molera Road	309.10.03	--	--	--	--	--	--	TO	--	--	--	--	--	--	--
Old Salinas River/Monterey Dunes Way Brg	309.10.04	--	--	--	--	--	TO	TO	--	--	--	--	--	--	--
Pajaro River/d/s Highway 1 Bridge	305.10.03	--	--	TOTM	TO	TOTM	TO	--	--	--	--	--	--	--	--
Pajaro River/Highway 129 Bridge	305.20.00	--	--	TOTM	--	--	--	--	--	--	--	--	--	--	--
Roberts Lake	309.10.01	--	--	--	--	--	--	--	--	--	--	--	--	--	TOTM
Salinas Rec Canal/u/s Tembladero Slough	309.10.06	--	--	--	--	--	--	--	--	--	--	TO	--	--	--
Salinas Reclamation Canal/Airport Road	309.10.17	--	--	--	--	--	--	--	--	TO	TO	--	--	--	--
Salinas Reclamation Canal/Davis Road	309.10.13	--	--	--	--	--	--	TO	TO	TO	TO	--	--	--	--
Salinas River Lagoon	309.10.00	--	--	--	--	--	TO	--	--	--	--	--	--	--	--
Salinas River No. 2	309.10.90	--	--	--	--	--	--	--	--	--	TO	--	--	--	--
Salinas River/Blanco Drain	309.10.05	--	--	--	--	--	TO	TO	--	--	--	--	--	--	--
Salinas River/Blanco Road	309.10.07	--	--	--	--	--	TO	TO	--	--	--	--	--	--	--
Salinas River/Gonzales	309.30.00	TOTM	TOTM	TOTM	--	TOTM	--	--	--	--	--	--	--	--	--
Salinas River/Mouth	309.10.18	--	--	--	--	TOTM	--	--	--	--	--	--	--	--	--
Salmon Creek	308.00.02	--	--	--	--	--	--	--	--	--	--	--	--	TM	--
San Antonio River/Highway G19	309.81.14	--	--	--	--	--	--	TM	--	--	--	--	--	--	--
San Clemente Reservoir	307.00.19	--	--	--	--	TM	--	--	--	--	--	--	--	--	--
San Lorenzo River/Big Trees	304.12.06	TOTM	TOTM	TM	TOTM	--	--	--	--	--	--	--	TOTM	--	--
San Lorenzo River/Graham Hill Road	304.12.09	--	--	TM	--	--	--	--	--	--	--	--	--	--	--
San Lorenzo River/Zayante Creek	304.12.10	--	--	TM	--	--	--	--	--	--	--	--	--	--	--
San Luis Obispo Creek/d/s SLO	310.24.02	--	--	--	--	--	--	--	--	--	--	--	TOTM	TOTM	--
San Luis Obispo Creek/u/s SLO	310.24.32	--	--	--	--	--	--	--	--	--	--	--	TOTM	TOTM	--
Santa Maria River/Mouth	312.10.00	--	--	--	--	--	--	--	--	--	--	--	--	--	TO
Santa Rosa Creek	310.14.03	--	--	--	--	--	--	--	--	TM	--	--	--	--	--
Schwann Lake	304.12.90	--	--	--	--	--	--	--	--	--	--	--	--	--	TOTM
Waddel Creek	304.10.02	--	--	--	--	--	--	--	--	--	--	--	--	TM	--
Watsonville Slough/Harkins Slough Road	305.10.06	--	--	--	--	--	--	--	--	TO	--	--	--	--	--
Watsonville Slough/Lee Road	305.10.07	--	--	--	--	--	--	--	--	--	--	TO	--	--	--
Watsonville Slough/San Andreas Road	305.10.02	--	--	--	--	--	--	TO	TOTM	--	--	--	--	--	--
Watsonville Slough/u/s Harkins Slough	305.10.05	--	--	--	--	--	--	--	TO	--	--	--	--	--	--
Whale Rock Reservoir	310.17.01	--	--	--	--	--	--	--	--	--	--	--	TOTM	--	--

* -- = Not Sampled. TO = Trace Organics Only. TM = Trace Metals Only. TOTM = Trace Organics and Trace Metals.

Recent Fecal Coliform Bacteria Testing Data

from Santa Cruz County Department of Environmental Health

ENVIRONMENTAL HEALTH WATER QUALITY MONITORING PROGRAM - WATSONVILLE SLOUGH

STANUM	LOCATION	DATE	TIME	TEMP-C	FECOLI	NOTES
P1065	HARKINS S @ HARKINS S RD BRIDG	06-Feb-90	11:20 AM	10	260	
P1065	HARKINS S @ HARKINS S BRIDGE	25-Feb-92	11:35 AM	15	0	CLEAR WATER
P1065	HARKINS S @ HARKINS S RD BRIDG	11-Jul-94			640	BROWNISH WATER.
P1065	HARKINS S @ HARKINS S RD BRIDG	12-Sep-94			380	GREYISH WATER.
P1065	HARKINS S @ HARKINS S RD BRIDG	13-Oct-94			40	BROWNISH WATER.
P1065	HARKINS S @ HARKINS S RD BRIDG	22-Nov-94	11:10 AM	9	380	GREYWATER.
P1065	HARKINS S @ HARKINS S BRIDGE	12-Dec-94		11	1120	GREYWATER. DUCKS.
P1065	HARKINS S @ HARKINS S BRIDGE	06-Feb-95			ERR	ROAD CLOSED DUE TO FLOODING.
P10528	STRUVE S @ AIRPORT B	04-Apr-89	02:05 PM	15.5	700	
P10528	STRUVE S @ AIRPORT B	04-Apr-89	02:15 PM	18	1950	
P10528	STRUVE S @ AIRPORT B	11-Apr-89	12:55 PM	18	11750	
P10528	STRUVE S @ AIRPORT B	18-Apr-89	10:15 AM	15	800	VERY LITTLE WATER FLOW
P10528	STRUVE S @ AIRPORT B	25-Apr-89	10:55 AM	15	7500	
P10528	STRUVE S @ AIRPORT B	02-May-89	12:30 PM		140	
P10528	STRUVE S @ AIRPORT B	16-May-89	10:05 AM	15	2010	LITTLE WATER FLOW
P10528	STRUVE S BELOW AIRPORT B	06-Mar-90	10:30 AM	14	220	GREYISH LOOKING WATER.
P10528	STRUVE S BELOW AIRPORT B	13-Mar-90	11:15 AM	14	350	GRAYISH WATER.
P10528	STRUVE S BELOW AIRPORT B	20-Mar-90	09:45 AM	14.5	1760	
P10528	STRUVE S BELOW AIRPORT B	27-Mar-90	11:35 AM	15	390	RUST COLORED WATER. LOW FLOW.
P10526	STRUVE S @ GREEN VALLEY RD	04-Apr-89	01:45 PM	17	700	
P10526	STRUVE S @ GREEN VALLEY RD	11-Apr-89	01:20 PM	23.5	200	
P10526	STRUVE S @ GREEN VALLEY RD	11-Apr-89	01:25 PM	22	180	
P10526	STRUVE S BELOW GREEN V RD	13-Mar-90	11:05 AM	9	520	
P10525	STRUVE S @ CHRISTIAN SCHOOL	04-Apr-89	01:35 PM	21.5	250	
P10524	STRUVE S @ LANDIS	11-Apr-89	01:40 PM	21.5	80	
P10521	STRUVE S @ LEE RD	11-Feb-92	10:40 AM	15	380	CLEAR WATER. RAIN 2/10
P10521	STRUVE S @ LEE RD	25-Feb-92	11:50 AM	20	80	ALGAL GROWTH
P10521	STRUVE S @ LEE RD	11-Jul-94			80	BROWNISH WATER. ALGAL GROWTH.
P10521	STRUVE S @ LEE RD	12-Sep-94			280	GREYISH WATER.
P10521	STRUVE S @ LEE RD	13-Oct-94			20	BROWNISH WATER.
P10521	STRUVE S @ LEE RD	22-Nov-94	10:02 AM	8	540	BROWNISH WATER.
P10521	STRUVE S @ LEE RD	12-Dec-94		11	820	GREYWATER.
P10521	STRUVE S @ LEE RD	06-Feb-95		14	0	FECAL COLI=19.9. GREYWATER. ORGANIC MATR
P10511	WATSONVILLE S @ LEE RD	22-Nov-94	10:51 AM	8	900	GREYWATER.
P10511	WATSONVILLE S @ LEE RD	06-Feb-95		13.5	460	OILY WATER.
P1051	WATSONVILLE S @ LEE RD	12-Dec-94		11	900	GREYWATER.
P105	WATSONVILLE S @ BEACH RD	06-Feb-95		14.5	140	BROWN WATER.
P101	WATSONVILLE S @ BEACH RD	21-Dec-87			20	MANY CLEAR FECAL COLIFORM COLONIES
P101	WATSONVILLE S @ BEACH RD	01-Feb-88			40	
P101	WATSONVILLE S @ BEACH RD	13-Jun-89	10:25 AM	22	10	GEESE & DUCKS ON SHORES
P101	WATSONVILLE S @ BEACH RD	11-Jul-94			840	BROWNISH WATER. SUSPENDED ORGANIC MATR.
P101	WATSONVILLE S @ BEACH RD	12-Sep-94			320	GREYISH WATER.
P101	WATSONVILLE S @ BEACH RD	13-Oct-94			80	BROWNISH WATER.
P101	WATSONVILLE S @ BEACH RD	22-Nov-94	10:41 AM	11	20	GREYWATER.
P101	WATSONVILLE S @ BEACH RD	12-Dec-94		11	860	GREYWATER.

ENVIRONMENTAL HEALTH WATER QUALITY MONITORING PROGRAM - WATSONVILLE SLOUGH SYSTEM

STANUM	LOCATION	DATE	TIME	TEMP-C	FECOLI	NOTES
P1065	HARKINS S @ HARKINS S RD BRIDG	11-Jul-94			640	BROWNISH WATER.
P1065	HARKINS S @ HARKINS S RD BRIDG	12-Sep-94			380	GREYISH WATER.
P1065	HARKINS S @ HARKINS S RD BRIDG	13-Oct-94			40	BROWNISH WATER.
P1065	HARKINS S @ HARKINS S RD BRIDG	22-Nov-94	11:10 AM	9	380	GREYWATER.
P1065	HARKINS S @ HARKINS S BRIDGE	12-Dec-94		11	1120	GREYWATER. DUCKS.
P1065	HARKINS S @ HARKINS S BRIDGE	06-Feb-95			ERR	ROAD CLOSED DUE TO FLOODING.
P1065	HARKINS S @ HARKINS S RD	01-May-95			650	BROWN WATER. RAIN 5/1/95.
P1065	HARKINS S @ HARKINS S RD	05-Jun-95			ERR	ROAD CLOSED.
P1065	HARKINS S @ HARKINS S RD	31-Jul-95			200	BROWN WATER. ALGAL GROWTH.
P10521	STRUVE S @ LEE RD	11-Jul-94			80	BROWNISH WATER. ALGAL GROWTH.
P10521	STRUVE S @ LEE RD	12-Sep-94			280	GREYISH WATER.
P10521	STRUVE S @ LEE RD	13-Oct-94			20	BROWNISH WATER.
P10521	STRUVE S @ LEE RD	22-Nov-94	10:02 AM	8	540	BROWNISH WATER.
P10521	STRUVE S @ LEE RD	12-Dec-94		11	520	GREYWATER.
P10521	STRUVE S @ LEE RD	06-Feb-95		14	0	FECAL COLI=19.9. GREYWATER. ORGANIC MATR
P10521	STRUVE S @ LEE RD	03-Apr-95	11:08 AM	19	40	BROWN WATER.
P10521	STRUVE S @ LEE RD	01-May-95			1000	BROWN WATER. RAIN 5/1/95.
P10521	STRUVE S @ LEE RD	05-Jun-95		21	380	BROWN WATER.
P10521	STRUVE S @ LEE RD	05-Jul-95		21	420	BROWNISH WATER.
P10521	STRUVE S @ LEE RD	31-Jul-95			100	ALGAL GROWTH. BROWN WATER.
P10511	WATSONVILLE S @ LEE RD	22-Nov-94	10:51 AM	8	900	GREYWATER.
P10511	WATSONVILLE S @ LEE RD	06-Feb-95		13.5	460	OILY WATER.
P10511	WATSONVILLE S @ LEE RD	01-May-95			1200	BROWN WATER. RAIN 5/1/95.
P10511	WATSONVILLE S @ LEE RD	05-Jun-95		21	1260	CLEAR WATER.
P10511	WATSONVILLE S @ LEE RD	31-Jul-95			30	BROWN WATER.
P1051	WATSONVILLE S @ LEE RD	12-Dec-94		11	900	GREYWATER.
P105	WATSONVILLE S @ BEACH RD	06-Feb-95		14.5	140	BROWN WATER.
P105	WATSONVILLE S @ BEACH RD	03-Apr-95	11:40 AM	19	240	BROWN WATER.
P105	WATSONVILLE S @ BEACH RD	01-May-95			700	BROWN WATER. RAIN 5/1/95.
P105	WATSONVILLE S @ BEACH RD	05-Jun-95		20.5	320	GREYWATER.
P105	WATSONVILLE S @ BEACH RD	05-Jul-95		20	640	BROWNISH WATER.
P101	WATSONVILLE S @ BEACH RD	11-Jul-94			840	BROWNISH WATER. SUSPENDED ORGANIC MATR.
P101	WATSONVILLE S @ BEACH RD	12-Sep-94			320	GREYISH WATER.
P101	WATSONVILLE S @ BEACH RD	13-Oct-94			80	BROWNISH WATER.
P101	WATSONVILLE S @ BEACH RD	22-Nov-94	10:41 AM	11	20	GREYWATER.
P101	WATSONVILLE S @ BEACH RD	12-Dec-94		11	860	GREYWATER.
P101	WATSONVILLE S @ BEACH RD	31-Jul-95			140	BROWN WATER.