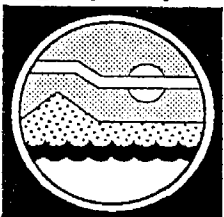


# SELENIUM AND AGRICULTURAL DRAINAGE STUDIES IN CALIFORNIA

Progress Report  
91-8-WQ

MAY 1991

WATER RESOURCES CONTROL BOARD  
STATE OF CALIFORNIA





SELENIUM AND AGRICULTURAL DRAINAGE STUDIES IN CALIFORNIA  
AGRICULTURAL DRAINAGE PROGRAM  
PROGRESS REPORT  
May 1991  
91-8-WQWR

Division of Water Quality and Water Rights  
State Water Resources Control Board  
State of California



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PROGRESS REPORT  
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## EXECUTIVE SUMMARY

### Purpose

Following the discovery of wildlife contamination at Kesterson Reservoir in 1983, State and Federal agencies initiated studies on selenium and agricultural drainage in California. The State Water Resources Control Board (State Board) Study Plan for the Agricultural Drainage Program was approved by the Legislature in 1985. The objective of the Study Plan was to complement the studies done by other State, Federal, and local entities. One element of the Study Plan is coordination among all the entities involved in the activities to help solve the selenium and drainage-related problems. This annual progress report is part of the coordination element to apprise all parties involved of the statewide efforts directed towards solution of selenium and agricultural drainage-related problems.

### Background Information

At present, there are about 4.7 million acres of irrigated land in the San Joaquin Valley (Valley) that use about 17.6 million acre-feet (MAF) of water each year. On the average there are 2,235,000 acres of irrigable land in the western part of the Valley. The total irrigation water applied in 1988 was 6.3 MAF. The San Joaquin Valley Drainage Program (SJVDP) estimates that there are 847,000 acres of land with shallow ground water within five feet from the ground surface. There are approximately 220,000 acres of land in the Valley where the concentration of selenium in shallow ground water exceeds 50 microgram/liter (or parts per billion (ppb)). Approximately 50,000 acres of this area have selenium concentrations greater than 200 ppb. Potentially, adverse environmental impacts can occur if shallow ground water containing selenium is drained and discharged to the rivers or ponds. Estimated problem water (subsurface agricultural drainage water with elevated levels of selenium) for the year 2000 is 314,000 acre-feet from approximately 444,000 acres of land on the west side of the Valley. Currently, there are 133,000 acres of tile drained lands in the west side of the Valley. It is estimated that the tile drained land for the year 2000 will be 360,000 acres.

The drainage water from the western part of the Valley is disposed of by deep percolation discharge to the San Joaquin River or evaporation ponds. Agricultural drainage from west side of the San Joaquin River Basin is discharged to the San Joaquin River through Salt and Mud Sloughs and several other drainage discharge points. The volume of agricultural drainage water discharged to the San Joaquin River is 35,000-56,000 acre-feet. The agricultural drainage water totalling 30,000 acre-feet from about 59,000 acres of land in Tulare Lake Basin is discharged to about 7,000 acres of evaporation ponds. In the past few years many State and Federal agencies have participated in conducting planning, studies, research, and monitoring and regulations in an effort to deal with drainage-related problems in the western side of the Valley. Brief descriptions of the principal findings and statuses of activities by these agencies are described in this report.

### Findings

Some specific topics, findings, and recommendations discussed in this report are as follows:

- o State Board selenium verification study results indicate that: adult sturgeon from the San Francisco Bay/Estuary show selenium bioaccumulation. Selenium in all media measured was the highest in Salt and Mud sloughs and decreased in the San Joaquin River towards downstream. Selenium was found at elevated levels in certain birds collected from some evaporation ponds in the Tulare Lake Basin.

Preliminary results from drainage reduction projects indicate that tiered water pricing encouraged water conservation. Water use efficiency was the highest for a subsurface irrigation method compared with three other methods. There appears to be a linear relationship between load and flow reduction.

The State Board has developed the San Joaquin River model and is developing other water quality-related models.

The State Board approved the Statewide Water Quality Control Plan: Inland Surface Waters Plan and Bays and Estuaries Plan on April 11, 1991. The plan contains a regulatory program for agricultural drainage waters of the State. Regional Water Quality Control Boards will now begin implementation of the Plan.

- o Central Valley Regional Water Quality Control Board (Central Valley Regional Board) water quality surveys in the San Joaquin Valley in water year 1990 indicate that concentrations of trace elements in water from some stations in the San Joaquin River continue to exceed water quality objectives to be met in 1991.

The westside creeks have little impact on San Joaquin River water quality.

Of the 226 streams surveyed Statewide, concentrations of trace elements were generally low. The most abundant trace element was boron.

The Lower Kings River survey indicated that water quality objectives were exceeded during the period of survey which coincided with the ongoing drought.

The water quality objectives for selenium and boron for Mud and Salt sloughs to be met in 1993 were exceeded in water year 1990. Preliminary estimates of mass loads entering and leaving the Grasslands Basin were made.

Three species toxicity tests in water from the San Joaquin River showed invertebrate toxicity about 50% of the times tested in 35 miles of reach of the River between Merced and Stanislaus Rivers. The toxicity was traced to off-target movement of pesticides from orchard crops in the area.

Water and sediments from evaporation ponds in the San Joaquin Valley were analyzed for trace elements. Results showed elevated concentrations above background levels. Concentrations of selenium, boron, and molybdenum remained constant while very high concentrations of uranium were found in water. Selenium and arsenic in sediments were high but did not exceed the Hazardous Waste soluble threshold limits of 5 and 1 ppm, respectively.

- o SJVDP recommended a plan to solve agricultural drainage-related problems in the west side of the Valley. The recommended plan calls for implementation of the following measures: source control; drainage reuse; evaporation systems; land retirement; ground water management; discharge to the San Joaquin River; and protection, restoration, and provision of substitute water supplies for fish and wildlife habitat. SJVDP followup is in the process of preparing an implementation strategy report which outlines actions needed to implement the recommended plan, responsibilities of all participating agencies, and funding sources. The strategy report will also include a monitoring program to evaluate the effectiveness of the SJVDP recommended plan.
- o Department of Water Resources (DWR) pond investigation is focused on evaporation pond management alternatives to make ponds less attractive to waterfowl, breaking the food chain in the ponds, and providing offsite compensation, and mitigation wetland. DWR has released a draft report on cumulative impact of evaporation ponds. The report outlines the impacts and benefits of evaporation ponds and describes pond management, compensation, and mitigation measures.
- o Studies by University of California researchers is focused on drainage water treatment, volatilization of selenium by plants, reuse of drainage water, and bioaccumulation and toxicity of various forms of selenium. Some specific research findings are discussed in this report.
- o Drainage dischargers in the western part of the San Joaquin River Basin have submitted their Drainage Operation Plans (DOPs) to the Central Valley Regional Board. DOPs use measures such as water conservation, drainage reuse and, tiered water pricing to reduce volume of drainage water.
- o The State Department of Food and Agriculture (DFA) is the lead agency on agroforestry programs. Agroforestry has potential benefits for drainage reduction, management of salts and trace elements, control of water table, and improvement of farm ecology. Currently there are about 500,000 trees planted in 500 acres of agroforestry plantation in the Valley. Selection of trees and the optimum management scheme to prevent salinity buildup and potential boron toxicity to agroforestry plantation are being studied. The potential wildlife impacts of agroforestry plantations are also being studied by researchers from universities and other agencies.
- o The U.S. Department of the Interior National Water Quality Program has completed the reconnaissance survey in the upper Sacramento River and a planning phase will follow. Detailed studies at Salton Sea and Tulare Lake have been completed, to be followed by a remediation phase. The Kesterson Reservoir remediation is underway.
- o The U.S. Bureau of Reclamation (USBR) is preparing a plan to meet the drainage needs of the San Luis Unit Service Area (SLUSA). The USBR preliminary report outlines treatment, source control, and disposal to resolve the drainage problems in the SLUSA.
- o Numerous other projects are underway by various entities that involve treatment of drainage water, efficient irrigation and drainage management, assessment of best management practices, drainage water reuse, agroforestry

plantation, evaporation ponds, and monitoring for various constituents of concern in evaporation ponds, drainage waters, and surface water bodies in the San Joaquin Valley.

### Report Organization

Agricultural drainage studies and activities of the State Board are presented in Chapter 1, and for the Central Valley Regional Board are discussed in Chapter 2. Chapter 3 addresses activities of SJVDP. Chapter 4 describes agricultural drainage reduction program, evaporation pond investigations and agricultural drainage monitoring activities of DWR. Chapter 5 focuses on DFA agroforestry efforts. Highlights of the research activities by the University of California Salinity/Drainage Task Force researchers are presented in Chapter 6. Other related activities by State and Federal agencies are briefly discussed in Chapter 7.

## Chapter 1 State Water Resources Control Board Agricultural Drainage Program

The Budget Act of Fiscal Year (FY) 1985-86 contained funds to begin the process of regulating subsurface agricultural drainage waters by the State Water Resources Control Board (State Board). General Fund appropriation for FY 1985-86 was \$2,270,000 (including 9.3 Personnel Years and funds for selenium studies). The concept of the Subsurface Agricultural Drainage Program (Drainage Program) was contained in the Budget Change Proposal for FY 1986-87 and was approved by the State Board and incorporated into the Governor's Budget. Currently, Drainage Program contract funds are \$700,000 annually. The Drainage Program objective is to develop information for implementation of a regulatory program for agricultural drainage waters for all areas of California.

The multi-element Study Plan called for problem identification, problem verification, and a regulatory program to protect the beneficial uses of water from potentially toxic trace elements found in subsurface agricultural drainage waters.

So far, the following have been accomplished: (1) monitoring efforts have identified sources of trace elements; (2) fish and wildlife verification impacts have been noted; (3) appropriate water quality objectives and criteria for certain constituents have been developed; (4) computer models as an evaluation tool have been developed; (5) laboratory quality control/quality assurance has been established, and (6) extensive coordination activities have been accomplished. A complete review of the selenium and agricultural drainage studies in California was published by the State Board in 1990 [1]<sup>1</sup>.

### I. General Overview Studies

#### A. Selenium in California-Volume 2, Critical Issues

Selenium in California-Volume 2, Critical Issues report was published in October 1990 [2]. This report focuses on selenium issues most critical to California. It addresses selenium and its relation to agriculture, selenium and human health, adverse effects of selenium on aquatic organisms, selenium deficiency and toxicity, and methods to minimize adverse effects of selenium. The report concludes that the three options to deal with selenium tainted drainage water (rising water table, reuse, and discharge to evaporation pond) are not desirable. The treatment of agricultural drainage waters is not economically feasible at the present time, however, studies on treatment technology should be pursued. The report suggests that irrigation efficiency should be improved to reduce the volume of drainage water.

To solve agricultural drainage-related problems measures such as providing education to water users and water managers, providing financial incentives for water conservation, alternative land uses and its benefit to society, and development of water marketing are recommended in the report.

<sup>1</sup> The number in bracket refers to the cited reference.

An overview of physical, chemical, and biological properties of selenium is given in Selenium in California-Volume 1 [3].

B. Wildlife Toxicological Assessment in the Geochemical Environment

A recent California survey of twenty trace elements in aquatic bird liver, fish liver, whole bivalves, insects, and waters from the aquatic ecosystems of the San Francisco Bay-Delta and the evaporation ponds in the San Joaquin Valley was used to analyze the interrelationship among trace elements [4]. The analysis is performed by the University of California Veterinary Diagnostic Laboratory at Davis under a contract with the State Board. The preliminary findings of the report are:

1. Statistical Interrelationship of Trace Elements in Aquatic Birds
  - a. The nearest neighbor correlation of trace elements in aquatic bird liver tissue indicates several clusters with strong interactions, including Cd-Mn-Se-Hg (Cadmium-Manganese-Selenium-Mercury).
  - b. Liver Se levels are significantly higher at the San Joaquin River input of the estuary than at the south bay.
  - c. Water Mn either affects the bioavailability of Se (Ruddy Duck at evaporation ponds) or it is an indicator of the redox potential of the ecosystems.
2. Geographical Distributions of Liver Trace Element Levels in the San Francisco Bay Estuary
  - a. Significant regional differences in several trace element concentrations are observed.
  - b. Se in birds from Suisun, San Pablo, and Central San Francisco Bays was the only trace element that had mean concentration in the range considered to be toxic to poultry.
3. Distribution and Diagnostic Range of the Liver Trace Element Levels
  - a. An exponential histogram method is used to show the comparative toxicological assessment of populations from trace elements. Concentration of selenium in bird liver from Suisun Bay was in the range considered to be toxic to poultry.
4. Preliminary Conclusions
  - a. The elevated levels of Se may be due to environmental Se exposure, an induction of protective enzymes, a response to heavy metal exposure, and a biogeochemical absorption or metabolic interaction.

- b. Trace elements interactions suggests that liver and kidney tissues use Se in the detoxification of Hg and Cd, hence other tissues (eggs, blood, muscle) may be a more specific indicator of environmental exposure of Se.

### C. Selenium Verification Study

Selenium Verification Study (SVS) began in 1985 as one element of the State Board Agricultural Drainage Program. The purpose of the study is to provide an intensive assessment of selenium and other trace elements in biota from the areas of concern in California. SVS has focused on various water bodies in the State. So far three SVS reports [5,6,7] have been published by the State Board. The fourth report (SVS 1988-1990) is in preparation [8]. The preliminary findings and conclusions of 1988-1990 report are as follows:

1. Selenium levels in adult striped bass from the Delta remain unchanged (0.39 ppm wet weight in flesh) and are similar to the national average for freshwater (0.49 ppm wet weight on a whole body basis). Selenium levels in adult white sturgeon are at elevated levels often exceeding 2 ppm wet weight, the State Department of Health Services's (DHS) interim internal guidance level used to screen sample data for potential hazard to human consumers.
2. Selenium levels measured in filtered water, suspended particulate, plankton, sediment, resident Corbicula, catfish, bass, bluegill show similar spacial trends in the San Joaquin River and Salt and Mud Slough tributaries. Selenium levels in all media are at the lowest in the San Joaquin River at Lander Ave, before the influence of the drainage water from the Grasslands area. The highest selenium levels are found in the drainage canals (Camp 13 Ditch and Agatha Canal) and Mud and Salt sloughs. Selenium levels found in the Delta were still higher than those at San Joaquin River-Lander Ave. Selenium levels in water and plankton from streams or canals in the Grasslands (Camp 13 Ditch, Agatha Canal, Mud and Salt Sloughs) periodically exceed 20 ppb and 2 ppm dry weight, respectively.
3. Invertebrate sampling from the evaporation ponds showed that there are significant differences in selenium levels between invertebrate species, among cells in a pond complex, and within a single cell of the same pond.
4. Black-necked stilts appear to be accumulating elevated levels of selenium (3-15 ppm wet weight in liver) while wintering at evaporation ponds in the San Joaquin Valley. Elevated levels of selenium have been associated with birds teratogenesis (deformities) and reduced hatching success.
5. Waterfowl (ruddy ducks, northern shoveler, northern pintail, mallards, and green-wing teal) collected from evaporation pond complexes showed significant levels of selenium in liver and muscle

tissues. The levels were significantly different from background levels in birds from Kern National Wildlife Refuge. Se levels in certain waterfowl (ruddy ducks and northern shoveler) exceed 10 ppm wet weight.

SVS 1990-91 is focused on the impact of selenium in the stream and back water areas of Mud Slough and San Joaquin River. The purpose of this study is to evaluate the levels of selenium in the aquatic organisms in these water bodies.

## II. Site Specific Studies

### A. Drainage Reduction Projects

In 1988, the State Board entered into an interagency agreement with the Department of Water Resources (DWR) to partially fund several agricultural drainage reduction projects in the San Joaquin Valley for a three-year duration. The projects are administered by DWR.

#### 1. Demonstration of Emerging Irrigation Technology for Drainage Reduction

This demonstration project was conducted in a 160 acre field in the west side of the San Joaquin Valley. Four irrigation methods are used to irrigate cotton: Low Energy Precision Application (LEPA), Subsurface Drip, Improved Furrow, and Historical Furrow (as managed by the growers). A report is expected in July 1991.

#### 2. Shallow Ground Water Management for Drainage Reduction

This project involves installation of shallow tile drain with flow control valves. The project has been delayed. A new contractor is being sought to conduct the study.

#### 3. Load/Flow Relationships

Drainage reduction is considered a necessary step towards resolving agricultural drainage-related problems in the Valley. It reduces the volume of drainage water to be treated or disposed of. However, the relation between drainage volume reduction and mass load reduction has not been studied thoroughly. The load/flow relationship project conducted by the staff of the U.S. Department of Agriculture, Agricultural Research Service and the U.S. Geological Survey (USGS) is designed to address this issue. A report is expected in early 1992.

#### 4. Ground Water Contribution to the San Joaquin River

USGS under a contract with DWR is preparing this report for the State Board. The final report will become available in late 1991 [9].



## 5. Irrigation Efficiency and Regional Subsurface Drainage Flows

This study was designed to evaluate the relationships among irrigation efficiency, drainage volume, crop type, and soil type. The field work was conducted at Panoche Water and Drainage District. DWR submitted the final report to the State Board in 1990 [10]. The report concludes that the preplant irrigation is a major source of deep percolation. Source control by irrigation management will significantly reduce drainage flows resulting from deep percolation. Improved irrigation management should be focused on upslope undrained area. Lateral flow into the district is not a major source of drainage water from the district.

### III. Modelling Studies

#### A. San Joaquin River Model

The San Joaquin River Model is an input/output model that was developed to quantify the sources of salts, boron, selenium, and molybdenum to the River. It has been used to evaluate drainage reduction scenarios and the probability of meeting certain water quality objectives in the River. During the past year, revisions have been made to the stochastic version and the ground water component of the model.

The major revisions to the stochastic version of the model include the consideration of corrections between input data and extension of historical records of input data by reoperation of eastside reservoirs. The ground water component of the model has been converted to empirical relationships. The ground water results compare very closely with the results of a recent USGS study of ground water flows to the River. The ground water accretions included in the Montgomery Engineers Central Valley Model (CVGSM) and the USBR San Joaquin Valley operations model (SANJASM) are currently being compared with the San Joaquin River Model and the USGS results.

The San Joaquin River Model was recently used to project River salinities for the summer of 1991. Projections were made for several possible management scenarios. The results were presented in the final report of the 1991 San Joaquin River Salinity Task Force in April 1991 (C. Kratzer, State Board).

The framework of a pollutant transport model of the San Joaquin River has been developed. Much of the modeling work in 1991-92 will focus on improvements to this model. The rest of the future work will involve further improvements to the stochastic version of the San Joaquin River model and attempting to link it to the USBR operations model.

#### B. Grasslands Area Model

The University of California, Berkeley/ Lawrence Berkeley Laboratory, under contract with the State Board, will soon begin work on a flow and water quality model of the Grasslands area. This model will allow for a

better understanding of the movement of pollutant loads within the Grasslands area. Also, it will be possible to feed the output from the model directly into the State Board's San Joaquin River Model as Salt and Mud sloughs input.

C. Best Management Practices (BMPs) Model

Subsurface agricultural drainage water containing salts, trace elements, and nitrates are known to affect surface and ground water quality in the Central Valley [11]. BMPs have been suggested as a means of controlling Nonpoint Source (NPS) pollution. The overall objective of this work is to assess the effectiveness of the proposed BMPs for control of agricultural NPS pollutants. In this work, conceptual models will be used to evaluate the potential for reduction and control of pollutants through BMPs. It also evaluates cost effectiveness of the BMPs. Currently the work is focused on nitrates and salinity. A report is expected in early 1992.

**IV. Regulations**

A. Regulation of Agricultural Drainage Waters

The State Board approved the statewide Water Quality Control Plan for Inland Surface Waters and Bays and Estuaries of California (Plan) on April 11, 1991 [12]. The Plan prepared by the Division of Standards and Assessment contains a program for regulation of agricultural drainage waters in the State. The California Regional Water Quality Control Boards will begin implementation of the Plan.

Chapter 2 California Regional Water Quality Control Board,  
Central Valley Region (Regional Board)

**I. GENERAL OVERVIEW STUDIES**

**A. Municipal and Industrial Discharge Survey for Selenium**

The California Legislature, through the Governor's 1985-86 budget, provided funding for an intensive look at municipal and industrial discharges for selenium. Selenium samples were taken from 109 discharge points and a final report on this investigation was prepared in 1988, approved by the Regional Board and transmitted to the State Board's program manager. A summary of these activities was presented in previous report [1]. Because selenium has occurred in only a few isolated instances in this survey, no further work was conducted.

**B. Survey of Tile Drainage Discharges into the San Joaquin River**

During 1986 and 1987, Regional Board staff completed three water quality surveys of tile drainage systems that are discharging into the San Joaquin River. The survey of over 300 sites in seven distinct zones in the basin was conducted because of concern for elevated levels of trace elements being found in tile drainage.

A report on this survey entitled "Water Quality Survey of Tile Drainage Discharges in the San Joaquin River Basin" has been prepared, approved by the Regional Board and transmitted to the State Board's program manager. A summary of that was presented in the 1990 report [1]. The report describes the ranges of salinity and 13 trace elements that were included in the survey. Only six of the original 13 elements analyzed occurred with frequency: arsenic, boron, chromium, molybdenum, nickel, and selenium.

In April 1990, a follow up survey was conducted which focused on uranium, vanadium, and hexavalent chromium, in addition to the elements previously analyzed. The inclusion of these elements was based both on elevated levels documented in tile drainage in the Tulare Lake Bed area as well as on potential toxicity to aquatic life from elevated levels of hexavalent chromium. A report on the findings of this investigation will be prepared in 1991. The results of the report will be used to establish regulatory priorities and discharger monitoring programs, including factors in the development of basin plan amendments.

**II. SITE SPECIFIC STUDIES**

Several site-specific studies were conducted in response to concerns that agricultural drainage including the trace elements it contains may be impacting beneficial uses. Most of the studies were directed at the occurrence of selenium; however, other trace elements commonly found in

drainage water were also considered. A summary of these investigations was presented in previous progress reports [1]. No additional studies were conducted this year. It is anticipated that there will be an increase in activity on discharges from the Delta Islands as a result of the Delta Hearing.

#### A. Waterfowl and Wildlife Refuges in the Central Valley

Because of the concern expressed that surface and subsurface tile drainage waters from irrigated agriculture may be impacting wildlife refuges, reconnaissance surveys were conducted at several refuges to determine if further evaluation is needed. Reports on four of these investigations were described in the August 1990 progress report [1]. The remaining area is the Mendota Wildlife Management Area. Regional Board staff conducted a reconnaissance survey for salts and trace elements in the water supply utilized by the Mendota Wildlife Management Area that comes from nonpoint source agricultural return flows. Preliminary findings show that periods of strongly elevated trace elements are entering the Mendota Wildlife Management Area from irrigated lands to the west. Regional Board staff are attempting to determine the source of these metals. Further monitoring was planned for the 1990 irrigation season; however, due to staff shortages, further evaluation has been put on hold.

### III. EVALUATION OF CORRECTIVE ACTIONS

#### A. Stream Quality Evaluations

Several stream water quality surveys were conducted to determine natural background quality, loads that may be entering main stem water supplies or analyses of water quality in relation to beneficial use impacts. Emphasis in this program has been on selenium although periodic monitoring has also been conducted for other trace elements. The data developed in these programs are being utilized in development of water quality objectives, setting baseline conditions for nonpoint source reduction programs, and as a database for modeling of the San Joaquin River system.

##### 1. San Joaquin River Survey (Water Year (WY) 1989)

This study is part of a continuing water quality monitoring program, initiated in May 1985, to evaluate the effects of subsurface agricultural drainage on the water quality of a 60-mile section of the lower San Joaquin River. Mineral and trace element concentrations were evaluated for WY 89 in the river from near Mud and Salt Sloughs to near Tracy. During critically dry WY 89, constituent concentrations were routinely higher than they were during the wet 1986 WY and often exceeded the water quality objectives that are to be met in 1991 as established in the December 1988 Basin Plan Amendment adopted by the Regional Board.

A report on this water quality survey has been prepared, approved by the Regional Board, and transmitted to the State Board's program manager [24]. Specific findings include:

- a. The highest selenium, boron, and salt concentrations continue to occur just downstream of the Mud and Salt Slough confluences with the San Joaquin River with concentrations decreasing downstream as each of the three east side rivers dilute the San Joaquin River.
- b. Concentrations show seasonal variations with the highest concentrations occurring during the nonirrigation season (October to March).
- c. The single noncompliance site for the approved molybdenum water quality objective (19ug/L) is upstream of subsurface agricultural inflows; therefore, noncompliance is likely due to natural conditions.

## 2. San Joaquin River Survey WY 1990)

This study continues the water quality monitoring program on the lower San Joaquin River initiated in May 1985. Mineral and trace element concentrations are evaluated for WY 90 in the river from near Mud and Salt Sloughs to near Tracy. The report shows that during critically dry WYs 1987, 1988, 1989 and 1990 constituent concentrations were routinely higher than they were during the wet 1986 WY. The concentrations continue to exceed the water quality objectives that are to be met in 1991 as established in the December 1988 Basin Plan Amendment adopted by the Regional Board.

A report on this water quality survey has been prepared, approved by the Regional Board, and transmitted to the State Board's program manager [22]. In addition to confirming trends described for WY 1989, findings for Water Year 1990 include:

- a. Throughout WY 90, a critically dry year, three sites exceeded the approved boron objectives. Two of the sites, the San Joaquin River at Fremont Ford and the San Joaquin River at Hills Ferry, are upstream of the Merced River inflow (objective, 2.0 mg/L). While the third, the San Joaquin River at Crows Landing is downstream of the Merced River inflow (objective 1.3 mg/l). Compliance with the objective at the first two sites is to begin in 1993 and the later objective in 1991.
- b. During WY 90, selenium concentrations in the San Joaquin River at both Hills Ferry and Fremont Ford exceeded both the 1993 objective and the WY 90 milestone for the upstream reach of the river. In the downstream reach of the river, the Crows Landing site exceeded both the objective and milestone, although concentrations rapidly diminished farther downstream.

- c. Lack of freshwater dilution is contributing to the higher concentrations found during the critically dry years.

### 3. Westside Creek Survey

Periodic monitoring by Regional Board staff has been conducted on several of the creeks which originate in the Coast Range and discharge into the San Joaquin River and Delta. Monitoring concentrated on boron and selenium levels of these intermittent creeks and whether continuous monitoring would be needed to assess significant loads of these two trace elements to the River and Delta. Monitoring was conducted at the time of initial outflows from these creeks between 1984 and 1988. A report for the survey has been finalized, approved by the Regional Board, and transmitted to the State Board's program manager [23]. Specific findings include:

- a. The calculated selenium mass loading from westside tributaries is only 3-6 percent of the annual loading discharged by the subsurface agricultural drains, and, therefore, is unlikely to be a significant source of selenium concentrations measured in the San Joaquin River.
- b. Greater than 75 percent of the selenium mass loading from the creeks is discharged from January to the end of March, a period of maximum dilution flows in the San Joaquin River.
- c. Similar mass loading was found for molybdenum.
- d. High loads of boron and salt were noted for these streams. However, the impact may be minimized because, as for selenium, over 75 percent of the estimated loading occurs from January to the end of March, the period with maximum dilution flows in the San Joaquin River.

Because preliminary estimates show that water quality from the streams draining the eastern slope of the Diablo Range has little impact on San Joaquin River water quality, no further water quality monitoring is proposed. The database and mass loading projections will be used in the Regional Board's evaluation of the timing of subsurface drainage water discharges to minimize impacts on downstream users.

### 4. Stream Background Survey

A one-time monitoring effort was conducted by Regional Board staff to determine the range of natural background concentrations of selected trace elements in natural streams. This monitoring effort was conducted to: (a) represent streams above significant discharges or land use that may alter stream quality, (b) represent streams at their highest flow periods (February-April), and (c) represent periods when no surface runoff is occurring by having at least a 10-day nonrain period prior to sampling. The main effort of this program is selenium concentrations; however, selected samples were

checked for other trace elements. Low level detection was used on all samples. A report on this one-time monitoring effort has been prepared, approved by the Regional Board, and forwarded to the State Board's program manager [25]. Specific findings include:

- a. Of the 226 streams sampled, overall concentrations of arsenic, boron, cadmium, chromium, copper, lead, molybdenum, nickel, selenium, silver, uranium, and zinc are low.
- b. The median electrical conductivity for all samples is 360 umhos/cm.
- c. The most abundant trace element detected was boron with a median total recoverable concentration of 80 ug/L, and approximately 25 percent of the streams tested showing a concentration in excess of 650 ug/L.

The data developed in this program assisted the Regional Board in understanding the relative distribution of selenium and this was used as background information in developing water quality objectives for the San Joaquin River and identifying additional areas where further source monitoring is needed. No further sampling is anticipated.

#### **IV. DEVELOPMENT OF OBJECTIVES**

##### **A. Beneficial Use Assessments (Surface Waters)**

As part of the process of amending the San Joaquin River Basin Plan, a review of selected beneficial uses of surface and ground waters was made. Efforts were concentrated on those waters affected by the discharge of agricultural subsurface drainage water. Six surface water surveys were made of water diversions and their type of use and a survey was made of the type of tributaries that are entering the Mud and Salt Slough system. Each of the surveys was used as a basis for review of the Basin Plan which was amended on December 8, 1988. No additional surveys are planned. Summaries of completed surveys were presented in previous progress reports [1]. The final study was completed this year.

##### **1. Tributaries to Salt Slough**

A field and aerial survey was made of the location of all the tributaries to Salt Slough, itself a primary tributary to the San Joaquin River. The water quality of all the tributaries to Salt Slough is highly influenced by management decisions which result in manipulation of the water system. Because of this operation and the large fluctuations in water quality, the beneficial uses of the tributaries to Salt Slough stand alone and cannot be considered to be the same as the beneficial uses of the slough itself. Large diversity in use and characteristics precluded further assessment of beneficial uses for the tributaries. A report on the survey has been prepared, approved by the Regional Board, and forwarded to the State Board's program manager [17]. The information developed in this

program was used to establish beneficial uses for Salt Slough during the San Joaquin River Basin Plan Amendment process.

B. Beneficial Use Assessments (Ground Waters)

The discharge of agricultural drainage water including that into evaporation basins like Kesterson Reservoir has raised concern that localized ground water impacts may be occurring that are affecting designated beneficial uses. Ground water surveys in three areas have been conducted; the south Grassland area, the Patterson-Westley area, and the Kesterson Reservoir area. The work on these are summarized in previous progress reports [1]. Further ground water work in the vicinity of the evaporation basins will continue as part of the regulatory process for these facilities. No additional studies have been conducted.

C. Discharge Assessment

Several site-specific assessments were conducted to determine the location and extent of agricultural surface and subsurface drainage water discharges. Initial efforts for the assessment of agricultural surface discharges has concentrated on those locations which carry a blend of surface and subsurface drainage water. Emphasis in this program is on selenium and other trace element sources. A summary of past activities has been presented in previous progress reports. A summary of recent activities is presented below.

1. Kings River Discharge Survey

Regional Board staff surveyed the lower Kings River between November 1988 and July 1989 to confirm beneficial uses, determine impacts of subsurface agricultural drainage discharges, and characterize other types of agricultural discharges. The Lower Kings River exceeded the water quality objectives during the period of the survey, which coincided with the ongoing drought. A final report has been prepared, approved by the Regional Board, and forwarded to the State Board's program manager [18]. Additional monitoring is recommended, particularly when the drought has ended and "normal water year" samples may be obtained. An implementation plan for the River, which includes additional investigation, will be developed with funds from the Basin Plan Update Program.

2. Grassland Area Discharge Survey WY 1989)

This investigation continues an evaluation begun in 1985 and assesses the effects of subsurface agricultural drainage on water quality of drains in the Grassland Area of western Merced County during WY 1989. Seasonal variations in constituent concentrations occurred in a manner similar to the three previous water years, with the highest levels occurring during the nonirrigation season (October to March). A final report was prepared, approved by the Regional Board, and forwarded to the State Board's program manager [20]. The report will be utilized in development and evaluation of future agricultural



drainage reduction programs in the San Joaquin River Basin. Specific findings include:

- a. The highest constituent concentrations continue to occur in the four southern boundary inflow points which carry a substantial portion of subsurface drainage water. Other inflows contain little selenium; however, elevated levels of salt and boron are present.
- b. The two main outflow points, Mud Slough (north) and Salt Slough, represent water quality of the blended drainage flowing from the Grassland Area to the San Joaquin River. The quality of both sloughs varied widely depending upon which slough was carrying the greatest portion of subsurface tile drainage water. During WY 89, Salt Slough appeared to carry the highest proportion of tile drainage based on elevated trace element concentrations.

3. Grassland Area Discharge Survey (Water Year 1990)

This investigation continued the evaluation of the effects of subsurface agricultural drainage on water quality of drains in the Grassland Area of western Merced County during WY 90. During critical WY 90, boron and selenium concentrations were elevated over those found during wet WY 86 in both Mud and Salt Sloughs, and frequently exceeded water quality objectives that are to be met in 1993 as established in the December 1988 Basin Plan Amendment adopted by the Regional Board. A final report was prepared, approved by the Regional Board, and forwarded to the State Board's program manager [19]. The report will be utilized in development and evaluation of future agricultural drainage reduction programs in the San Joaquin River. In addition to confirming previous findings, the current findings include:

- a. The quality of the two main outflows, Mud Slough (north) and Salt Slough, varied widely depending on which slough was carrying the greatest portion of subsurface tile drainage water.
- b. During WY 90, the 1993 monthly mean molybdenum objective (19ug/L) was only exceeded on one occasion in Mud Slough and was not exceeded at any time in Salt Slough. In contrast, the 1993 mean monthly boron objective (2.0 mg/L) was consistently exceeded in both sloughs during WY 90.
- c. The selenium milestone for WY 90 (20 ug/L) was exceeded between January and June 1990 in Salt Slough with the maximum monthly mean reaching 29 ug/L. Mud Slough (north) did not exceed the 1990 milestone for selenium during WY 90.

Continuing drought conditions during WY 91 may increase difficulties in meeting future milestones and objectives for both sloughs.

4. Grassland Basin Discharge Loads

As part of the basin plan amendment process, Regional Board staff have evaluated the various loads of salt and trace elements that are leaving the Grassland Basin through Mud Slough (north) and Salt Slough. In addition, preliminary load estimates were made for various points entering the Grassland Water District. These estimates remain preliminary because flow data leaving the districts is still preliminary. Future work will include concentration monitoring to upgrade and refine these preliminary estimates. A draft report on the Grassland Basin loads was prepared in 1989. A follow-up report, incorporating recent data and improvements in flow monitoring, will be prepared in 1991.

#### 5. Toxicity Testing

Regional Board staff recently finished a two-and-a-half year survey of biotoxicity in the San Joaquin watershed. The purpose of the study was to characterize water quality in the River and its principal tributaries, and if impairments were observed, attempt to identify the chemical(s) causing toxicity.

The study employed EPA three-species protocols. The procedures estimate the acute and chronic response of organisms from phyla (fish, zooplankton, and algae) in water from the various sites as an assessment of instream toxicity. EPA has evaluated the utility of the test in eight studies and has found that instream toxicity, as measured by the three species protocol, was directly correlated with aquatic community degradation (measured as decrease in the number and kind of organisms present). More recent EPA procedures have established methods for assessing the chemical cause of toxicity.

The principal finding was the measurement of invertebrate toxicity at about 50 percent of the times tested in a 35-mile stretch of the San Joaquin River between the confluence of the Merced and Stanislaus Rivers. The cause of toxicity appears to be off-target movement of pesticides from row and orchard crops in Stanislaus and Merced Counties. Ethyl parathion, diazinon, carbaryl, and carbofuran have been measured in the River at concentrations in excess of both EPA recommended criteria and literature values reported to be acutely toxic to invertebrates. Regional Board staff have written several memoranda reporting on various toxicity-pesticide findings. Staff expect to complete a report summarizing all the results in 1991.

#### 6. Drain Locations and Installation Dates-San Joaquin River Basin

As part of the assessment of the impacts of tile drainage, Regional Board staff, in cooperation with the irrigation and drainage districts in the area, collected information on the location of all subsurface drains in the San Joaquin River Basin. This information was used to design monitoring programs. In addition, the information was used to determine the rate of installation of subsurface drains. No further assessment of drain locations is anticipated. No formal report on this activity is planned. A draft memorandum and series of maps delineating drain location and year of installation has been

prepared and is on file in the Central Valley Regional Board's Sacramento office.

#### 7. Solano Irrigation District Discharges

Past monitoring of Cache and Lindsay Sloughs have shown detectable levels of selenium. Although these concentrations are below the drinking water standard, a primary beneficial use of these sloughs, they may be impacting wildlife uses as these sloughs normally have poor outflow characteristics, thus acting as impounded waters. Initial Regional Board efforts are directed at identifying and monitoring the sources of this selenium. Preliminary results to date indicate that nonpoint source runoff and seepage, especially during the irrigation season, may be the key factor in the present selenium levels in the sloughs. Additional confirmation monitoring has been put on hold due to staffing shortages.

#### D. Basin Planning - Water Quality Objectives

The State Board, as part of Order WQ 85-1, directed the Central Valley Regional Board to adopt water quality objectives for the San Joaquin River and implement a program to regulate agricultural subsurface drainage water discharges. As part of that effort, the Regional Board adopted amendments to the basin plan on December 8, 1988. The adopted amendments and the supporting information were transmitted to the State Board where they were approved in September 1989. Implementation is under way. In addition, activities were undertaken in four supporting activities.

##### 1. Basin Plan Amendment for Pesticides

In addition to the Basin Plan Amendment for controlling agricultural subsurface drainage, the Regional Board considered and adopted a basin plan amendment for the control of pesticides in surface waters. Under the program established by the amendment, the Regional Board will regularly review monitoring results and target for control efforts those pesticides that pose the greatest threat to beneficial uses. Part of the implementation program establishes a time schedule for dealing with pesticides that are discharged via irrigation return flows. Five specific pesticides that have caused impacts to beneficial uses are also subject to a conditional prohibition of discharge. This conditional prohibition requires development and implementation of management practices that meet specified performance goals.

##### 2. Panoche Fan Ground Water Hydrology

To meet the water quality objectives, those areas that influence the quantity and quality of flows into the San Joaquin River must be regulated. Areas known to have a strong influence on river water quality and flow volumes are the tiled areas that discharge subsurface agriculture drainage water into the river. In addition, areas that are upslope from the tile drained areas may indirectly

influence the quality and quantity of the subsurface agricultural discharges. Water moving past the crop root zone in these areas eventually moves downward into the ground water and then downslope, thus increasing the volume and loads of the tile drainage water.

The Regional Board has begun preliminary efforts to evaluate the hydrogeology in the west-central San Joaquin Valley in order to determine how irrigation practices influence ground water levels and flow directions and how these practices may contribute to the drainage problem in the tile drained areas. The study area is the two major water-bearing zones present in the western San Joaquin Valley between Los Banos and Tranquility (Panoche Fan area).

A number of ongoing studies by the USGS and others will be utilized to conduct this study. If features can be defined well enough, specific areas that are likely contributing or might contribute to the problem will be identified. A report on this effort will be prepared as part of the triennial basin plan review.

3. Participation in the Development of Water Quality Objectives in the Inland Surface Water Plan

Regional Board staff assisted State Board staff in reviewing proposals for development of water quality objectives for agricultural drains. As part of the statewide effort to develop water quality objectives for all surface waters, agricultural drains became a significant area of controversy. Regional Board staff prepared a staff report on agricultural drains and a proposed approach to beneficial uses in these drains. These and other issue papers served as background material for the inland surface waters plan. The Inland Surface Waters Plan (Plan) was adopted in April 1991 and the Central Valley Regional Board's Basin Plans will be modified to reflect the new objectives. The Regional Board will prepare a workplan to implement the Plan especially for agricultural drains.

4. Use-Attainability Analysis

The disposal of agricultural drainage water raises issues about beneficial use protection and the need to develop site-specific objectives. These issues are best handled through the Use-Attainability Process defined in the Federal Clean Water Act. Because of the need to interface this process with existing State law and State Board policies, a task force was formed to determine the correct procedures for conducting such an analysis. This task force is ongoing at present.

## V. REGULATIONS

### A. Evaporation Basins in the San Joaquin Valley

With the lack of a cost effective outlet for subsurface drainage water from the southern San Joaquin Valley, farmers have installed evaporation

basins as a means of disposing of the drainage water. These basins remain an interim disposal method that must be worked into the long-term disposal plans. Our experience in managing these facilities, however, is limited and concern has been raised that these basins may be building up toxic levels of trace elements. The Regional Board began efforts to characterize these basins in 1985. Earlier studies have been utilized in setting regulatory requirements. The following six studies are involved in this effort and have expanded the informational data base.

1. Water Quality in Evaporation Basins (1988 and 1989)

This investigation evaluates mineral and trace element concentrations in inflow and ponded water found in agricultural evaporation basins during 1988 and 1989, as compared to concentrations found in sea water and natural saline lakes. Boron, arsenic, selenium, molybdenum, uranium, and vanadium continue to be found at concentrations elevated over background levels. Staff surveyed 27 existing ponds to compile data for the investigation. A final report has been prepared, approved by the Regional Board, and forwarded to the State Board's program manager [15]. The information will be used to evaluate the basin water concentrations as they relate to the Toxic Pits Cleanup Act (TPCA). Specific findings include:

- a. A number of trace element concentrations do not appear to have changed since 1985. Selenium, molybdenum and boron concentrations have all remained fairly constant over time. Arsenic and vanadium are the only trace elements that appeared to have increasing concentrations.
- b. Of the elements analyzed, only vanadium concentrations were lower in the ponded basin water than in the inflow.
- c. Geologic setting continues to influence trace element concentrations in both the inflow to and ponded water within the basins. Selenium and boron continue to be found at the highest concentrations in alluvial fan settings while arsenic, molybdenum and vanadium have their highest concentrations in lake bed settings.
- d. Extremely high total recoverable uranium concentrations found in the evaporation basins indicated the possibility of elevated uranium by-products, such as radium 226 (Ra226). However, no radium concentrations detected in the agricultural basins exceeded the Federal and State Drinking Water Standard (5 pCi/L). No standards are available for aquatic life.

The Regional Board will continue to conduct annual water compliance monitoring at each evaporation basin. Information from the survey completed in June 1990 will be available in report format in 1991.

2. Sediment Quality in Evaporation Basins (1988 and 1989)

This investigation evaluates mineral and trace element concentrations in sediment found in agricultural evaporation basins during 1988 and 1989, as compared to background levels described for the western United States, California, and Kesterson National Wildlife Refuge. Boron, arsenic, selenium, molybdenum and uranium continue to be found at concentrations elevated over background levels. A final report has been prepared, approved by the Regional Board, and forwarded to the State Board's program manager [14]. The information will be used to evaluate the basin sediment concentrations as they relate to TPCA. Specific findings include:

- a. Only the geometric means of molybdenum and boron greatly exceeded means for the comparison data. However, for three additional elements, the high end of the evaporation pond concentration range far exceeded those of the comparison. The three elements included arsenic, selenium, and uranium.
- b. Geologic setting appeared to influence sediment concentrations for selected elements. Boron and selenium were found in the highest concentrations in the alluvial fan area, while arsenic and molybdenum had their highest concentrations in lake bed sediments. Higher concentrations of uranium were found in the basin trough.
- c. Results from transect sampling indicated that all the elements sampled showed deviation based on sample location. The past history of wetting and drying of each cell appeared to influence the relative sediment concentrations within that cell. Areas where water historically has remained the longest (or ponded up) during the cell's drying cycle contained the highest sediment concentrations for elements known to remain in the water column-- notably arsenic, selenium, molybdenum, and uranium.
- d. Although arsenic and selenium were considered likely elements to exceed the Hazardous Waste soluble threshold limit (5 mg/L and 1 mg/L, respectively), none of the results exceeded the limits.

The Regional Board will continue to conduct annual sediment compliance monitoring at each evaporation basin. Information from the survey completed in June 1990 will be available in report format in 1991.

### 3. Biological Characterization of the Evaporation Basins

Since the closure of the San Luis Drain and Kesterson Reservoir, concern has been expressed whether contamination problems, similar to those experienced at Kesterson Reservoir, will arise as the result of using evaporation ponds for the disposal of tile drainage water. It is necessary to identify ways, through proper design and management of evaporation ponds, to minimize the potential for such contamination problems to develop.

In previous studies, through the University of California, Davis, three reports were prepared which: (1) discussed the biological components in evaporation basins, (2) presented a comprehensive bibliography of the literature dealing with highly saline aquatic environments, and (3) reviewed information available on tolerances of commonly occurring aquatic organisms to salinity, temperature, pesticides, and trace elements. These reports were discussed in more detail in previous progress reports [1].

A fourth report [16] was finalized in 1990 and reviews appropriate methods for obtaining representative samples of the biological communities which exist in the basins. Both methods of estimating population densities of pond dwelling organisms, as well as methods for collecting suitable quantities of biomass for trace metal analysis and tissue burden studies were developed. Use of these characteristic indices is important in determining the potential for contamination to wildlife resulting from food chain bioaccumulation of toxic constituents present in agricultural drain water.

Further monitoring and site characterization is presently under way to further characterize the basins and their food chain. A final report on this activity will be prepared in early 1991.

#### 4. Analytical Methods for Evaporation Basin High Salt Water

Regional Board staff began an extensive program to characterize water quality at evaporation basin sites in the San Joaquin Valley during 1985. The data, however, for some elements, showed inconsistent analytical results for water quality samples taken from similar sites or basins and raised serious concern for the accuracy of data being collected by agencies and dischargers.

The difficulty in analysis appears to be that standard laboratory procedures used for drinking and irrigation water encounter considerable salt matrix interferences when working with the highly saline waters of the evaporation ponds. Regional Board staff initiated a study with the University of California, Riverside, to develop reliable analytical techniques for trace elements to be used in monitoring agricultural subsurface drainage water evaporation ponds.

The study confirmed previous findings that only eight of over 40 elements analyzed appear to be elevated in the evaporation basins-- boron, chloride, sodium, arsenic, molybdenum, selenium, uranium and vanadium. Although the investigation also developed an analytical methodology for multiple element analysis, the needed equipment, modification and cost, along with the need to develop specialized expertise, restricts the use of this methodology to a research environment. The eight primary elements of concern can be analyzed separately by relatively conventional methods so the full scan provided by the highly specialized method does not provide the Regional Board with any additional regulatory tools. The final report was approved by the Regional Board and forwarded to the State

Board's program manager [13]. No further investigation into analytical methods is anticipated.

5. Natural Saline Lakes Survey

A water quality survey was conducted on 15 inland saline-sink lakes in the western United States to determine if trace element accumulation evident in agricultural drainage water evaporation basins occurs under natural conditions. The natural saline lakes did not appear to show the extent of trace element accumulation found in the agricultural evaporation basins. The natural salt lakes varied greatly in mineral and trace element concentration and in almost all instances showed concentrations less than those found in the evaporation basins. Although showing a significantly lower trace element concentration, the natural salt lakes displayed a characteristic similar to the evaporation basins in that they showed trace element accumulation at concentrations higher than seawater. This accumulation was greatest for arsenic, boron, molybdenum, uranium, and vanadium.

A final report was prepared, approved by the Regional Board and forwarded to the State Board's program manager [21].

6. Cumulative Wildlife Impacts at Westside Agricultural Drainage Basins

The Regional Board, because of its regulatory role over subsurface agricultural drainage evaporation basin (basins), has been caught up in mitigation of wildlife impacts. Reduced hatchability or deformities of birds have been noted by the U.S. Fish and Wildlife Service at some of the basins. When an environmental assessment and a proposed negative declaration were circulated for one of the pending WDRs, Department of Fish and Game (DFG) objected. Although the project proponents had entered into agreement with the DFG to mitigate adversely effects of pond operation on waterfowl, DFG responded that completion of the actions in the agreement would not mitigate cumulative impacts.

The Regional Board responded by conducting public meetings for exchange of information on wildlife impacts. In August 1989, the Regional Board directed staff to have pond operators prepare a technical report (TR) to serve as a draft Environmental Impact Report (EIR) focused on cumulative wildlife impacts.

The pond operators formed a nonprofit corporation called "Central Valley Agricultural Pond Operators" (CVAPO). A small "advisory" group (staff, DWR, DFG, CVAPO) was also formed to define the scope and guide the development of the draft TR.

The TR identified and assessed the beneficial and adverse cumulative environmental effects on wildlife. The TR also proposed and evaluated alternative methods for mitigation of any potential adverse cumulative impacts. The mitigation actions identified in the report will be considered by the Regional Board for inclusion in WDRs.



The TR was circulated by DWR with comments due May 1, 1991. Upon acceptance by the Board, the TR will be circulated as a cumulative EIR focused on wildlife impacts through the State clearinghouse.

## VI. REGULATORY

The Regional Board has undertaken several recent actions for full implementation of a regulatory program.

### A. Basin Plan Implementation (Drainage Operations Plans)

As described in Section IV.D., a basin plan amendment was adopted for the regulation of agricultural drainage in the San Joaquin River Basin. The amendment included water quality objectives and an implementation plan. The implementation plan called for submission of drainage operation plans (DOPs) by each district discharging subsurface or surface agricultural drainage. Drainage operation plans (DOPs) and water quality objectives are integral parts of the Regional Board's approach to control of subsurface flows. The DOPs are to be prepared by the dischargers and document their efforts to improve water quality.

Water quality objectives and the requirement for DOPs are contained in Regional Board Resolution No. 88-195, dated December 1988, which amended the Basin Plan for the San Joaquin River Basin. This Basin Plan Amendment was subsequently approved by the State Board (Resolution 89-88) in September 1989. The DOPs are required to be submitted on an annual basis. Water quality objectives were established for selenium, boron, and molybdenum. According to the Amendment, the control of toxic trace elements, especially selenium, is the first priority. The first DOPs were submitted in December 1989.

The second set of drainage operation plans were requested in June 1990 from water districts and drainage districts, as well as State and Federal agencies which manage wildlife refuges or deliver water in the Grasslands Basin. Each contributes in varying degree to subsurface drainage flows. They were requested in their drainage operation plans to discuss management options, water conservation policies, and water reuse practices and relate them to water quality objectives. These DOPs were due in December 1990.

Drainage operation plans were submitted by all those requested to do so. Eighteen drainage operation plans were received. The DOPs are under review. The DOPs discuss a variety of approaches including water conservation, water pricing, treatment processes, reuse of water, research studies and administrative needs. Many, but not all, of the districts either have some kind of water conservation and/or water reuse program. Districts have made or will be making capital improvements to expand their capability to reuse drainage water, control irrigation timing or reduce seepage in canals.

### B. Basin Plan Implementation (Water Conservation Practices)

Because of the complexity of evaluating the Drainage Operations Plans, a study was funded by the Regional Board which evaluated irrigation efficiencies in four of the six districts with high selenium. These districts showed an average improvement in irrigation efficiencies of about 12 percent since 1985. However, one district (Pacheco Water District) has fallen behind the others in overall efficiency. Two of the districts have shown close to a 20 percent improvement in irrigation efficiencies since 1985. This evaluation of irrigation efficiencies is planned to be expanded to the other two districts which are high in selenium. A report on this analysis is planned for early 1991. In addition to this report, Regional Board staff conducted a survey of on-farm water conservation practices in eight major districts in the Grassland Basin. A summary of this work has been prepared and the results used to evaluate the DOPs submitted in 1990. In this summary, the staff analysis shows that the water conservation practices that growers used most often were short furrow lengths, irrigation scheduling, and tail water return systems.

#### C. Drought Concerns - San Joaquin River

Based on all current indications, in late 1990, the State of California was facing the fifth year of a drought. Stored water supplies in the San Joaquin River Basin were at or near an all-time low in most reservoirs, with some dropping to near minimum pool levels.

Current demand in the San Joaquin River Basin indicated a strong likelihood that there may not be enough water in 1991 to serve all beneficial uses of water. Instream flow may be at an all-time low.

Due to the continued drought conditions, downstream water users are concerned about the degradation of the quality of the limited supplies that may be available, especially the projected salinity levels. Due to the extreme drought and likelihood of serious downstream impacts, the Regional Board and others needed to explore what short-term measures could be taken to minimize or eliminate downstream impacts. The Regional Board was considering the need to hold a public workshop to consider whether agricultural subsurface drainage flow to the San Joaquin River can be curtailed or reduced during this fifth straight critically dry year. Such discharges to the river during WY 1991 could have a serious impact on beneficial uses in the river. The workshop would serve as a public forum to discuss options for handling the drainage water this year and mechanisms for implementation of such options. Comments and suggestions would be received regarding actions that the Regional Board, other state agencies, local agencies and private entities may take to mitigate the effects of the drainage water on the river during this water year.

#### D. Waste Discharge Requirements (WDR)

Preparation has begun on WDRs on several of the evaporation basins in the Tulare Lake Basin. Draft requirements on one facility have been issued; however, adoption of these has been delayed because of environmental concerns raised about the cumulative impact of a large number of

evaporation basins being located in the San Joaquin Valley. An environmental document is now under preparation and adoption of WDRs will proceed immediately thereafter.

The Central Valley Regional Board also adopted waste discharge requirements for the one-time dewatering of Kesterson Reservoir in 1989. This was needed to allow the USBR the needed time to close the site per the State Board's order. Additionally, a six-month permit was adopted to allow for the discharge of ground water that accumulated in the San Luis Drain. This discharge is needed to avoid overtopping of the drain and flooding of adjacent farmlands. This permit was reissued during 1990.

WDRs were prepared for the closure of Kesterson Reservoir in 1989. These requirements were placed in abeyance by the State Board when the final closure method was changed. A portion of the requirements remained in effect for the needed wetlands mitigation. The discharger has submitted a mitigation plan that provides for no net loss of wetlands habitat values or acreage. This plan was approved by the Central Valley Regional Board and implementation is underway. In addition, the Regional Board has received and approved the annual management plan for the Kesterson Reservoir. The Regional Board continues to review and evaluate the site monitoring program.

#### E. Compliance Monitoring

Monitoring of water quality on the San Joaquin River, Mud Slough (north), and Salt Slough has continued in order to compare accomplishments with adopted water quality objectives. Monitoring has also been continued on the evaporation basins as required by recent legislation.



## Chapter 3 State-Federal San Joaquin Valley Drainage Program

### I. San Joaquin Valley Drainage Program

The San Joaquin Valley Drainage Program (SJVDP) was established in 1984 to investigate agricultural drainage and drainage-related problems and find and recommend measures to solve immediate and long-term agricultural drainage-related problems in the San Joaquin Valley. SJVDP was formed as a joint State-Federal program. SJVDP completed its mission in September 1990 and released a final report [26].

Based on a SJVDP preliminary alternatives report [27] on the average there are 2,235,000 acres of irrigable land in the western part of the Valley. The total irrigation water applied in 1988 was 6.3 million acre-feet. SJVDP estimates that there are 847,000 acres of land with shallow ground water within five feet from the ground surface.

There are approximately 220,000 acres of land in the San Joaquin Valley where the concentration of selenium in shallow ground water exceeds 50 microgram/liter (or parts per billion (ppb)). Approximately 50,000 acres of this area have selenium concentrations greater than 200 ppb. Potentially, adverse environmental impacts can occur if shallow ground water containing selenium is drained and discharged to the rivers or ponds.

The drainage water from the western part of the Valley is disposed of by discharge to the San Joaquin River or evaporation ponds. The volume of agricultural drainage water discharged to the San Joaquin River is 35,000-56,000 acre-feet [27]. Agricultural drainage water from the west side of the San Joaquin River Basin is discharged to the San Joaquin River through Salt and Mud Sloughs and several other drainage discharge points.

Soils of the most part of the west side of the Valley are formed through natural erosion of marine sediments in the Coast Ranges. The soils have low permeability and high salinity. Ten percent of the Valley soils have selenium concentrations greater than the national median of 0.3 milligrams/kilograms (mg/Kg). The Valley median is 0.13 mg/Kg and concentrations as high as 4.5 mg/Kg occur in alluvial-fan material derived from erosion and weathering of the coast range rocks. Trace elements and salts are leached from soils into the ground water as a result of intensive irrigation of the west side soils. The net accumulation of salt in the west side is 3.3 million tons per year. The water table has risen and the concentration of selenium and other trace elements and salts has increased in the shallow ground water. The salt buildup and high water tables adversely affect the productivity of agricultural industry.

SJVDP final report contained a recommended plan to solve agricultural drainage problems in the Valley. Seven actions were recommended: (1) source control, (2) ground water management, (3) discharge to the San Joaquin River, (4) reuse, (5) evaporation ponds, (6) land retirement, and (7) protection,

restoration, and provision of substitute water supplies for fish and wildlife habitat.

Estimated problem water (subsurface agricultural drainage water with elevated levels of selenium) for the year 2000 is 314,000 acre feet from approximately 444,000 acres of land on the west side of the San Joaquin Valley. Currently there are 133,000 acres of tile drained lands in the west side of the Valley. It is estimated that the tile drained land for the year 2000 will be 360,000 acres. The tile drained lands for year 2040 will be 783,000 acres.

The land areas (acres) under drainage management in the recommended plan for the year 2040 are as follows:

Source control	675,500
Drainage reuse	48,900
Evaporation ponds	7,600
Evaporation pond alternative habitat	4,500
Land retirement	75,000
Ground water management	69,000
Land discharging to San Joaquin River	160,600

The volume of water becoming available by year 2040 through land retirement, ground water management, and source control are 196,000, 56,000, and 308,000 acre-feet, respectively. The volume of water becoming available annually through combined land retirement, ground water management, and source control for year 2000 and 2040 are 242,000 and 560,000 acre-feet per year, respectively. The annual additional water needs for the fish and wildlife for year 2000 and 2040 are 167,000 and 193,900 acre-feet/year, respectively.

During 1990, several technical reports were published by the SJVDP and its member agencies. A brief description of findings from selected reports are given hereafter.

A. Geological Sources, Mobilization, and Transport of Selenium From the California Coast Ranges to the Western San Joaquin Valley: A Reconnaissance Study [28].

A reconnaissance sampling of water, soil, evaporative salts, and bedrock from a 1,000 square mile area in the west side of the San Joaquin Valley has been conducted. The study identified the source and mechanisms of selenium transport in the study area. Elevated concentrations of selenium are found in the pyritic shales of the Upper Cretaceous-Paleocene Moreno and Eocene-Oligocene Kreyenhagen Formations. These Coast Range formations are the primary source of selenium to the west side of the San Joaquin Valley. The authors conclude that selenium is mobilized by oxidative weathering of pyritic shales. The alkaline oxidative conditions of these systems provides proper conditions for formation and transport of selenate. The authors suggest that a sulfate

chemical regime dominates the Coast Ranges waters that drain into the west side of the San Joaquin Valley. The sodium and magnesium sulfate minerals are identified as the temporary sinks for selenium. Elevated levels of selenium are found in ephemeral stream waters, in runoff waters from rainfall events, in the soil unsaturated zone, and in ground waters in the area. Two mechanisms of transport are identified: (1) movement of water soluble selenate, the most oxidized form of selenium. Selenate is formed as a result of oxidative process and is transported with water, (2) movement of residual particulate insoluble selenium. Erosion is the primary cause of the movement of residual selenium. The report concludes that in the arid climate of the west San Joaquin Valley, it is expected that wetting and drying cycle will continue to mobilize selenium and pose a threat to beneficial uses of waters in the San Joaquin Valley.

B. Geochemical Relations and Distribution of Selected Trace Elements in Ground Water of the Northern Part of the Western San Joaquin Valley, California [29].

This report was published by the USGS. The study involved collecting well water samples from the northern part of the western San Joaquin Valley to determine the distribution and geochemical relations of several constituents in the ground water. The data was collected in 1985. Both semiconfined aquifer and confined aquifer water samples were analyzed. The data presented indicate that the ground water chemistry in the study area has been affected by agricultural and natural sources of recharge. Data indicate that irrigation water has infiltrated into both semiconfined and confined aquifers. It is suggested that the movement of water from semiconfined aquifer to the confined aquifer is likely occurring by the wells perforating the low permeable clay layer separating the two aquifers. Trace elements concentration in the semiconfined and confined aquifers are found to be similar. However, the concentration of constituents (nitrate, boron, and selenium) in ground water from Coast Ranges sediments are significantly higher than those in ground water from Sierra Nevada sediments. Selenium concentration greater than the U.S. Environmental Protection Agency (EPA)'s drinking water standard of 10 ppb was found in one well from the confined aquifer and two wells from the semiconfined aquifer. Statistical analysis of the interrelationship among trace elements show association among selenium, chromium, lithium, and boron. These elements are also associated with the Coast Ranges sediments. Arsenic, iron, manganese, and molybdenum associated with the Sierra Nevada sediments also show positive correlation.

C. Fish and Wildlife Resources and Agricultural Drainage in the San Joaquin Valley, California, Volume I and II [30].

This report was prepared by U.S. Fish and Wildlife Services (USFWS) staff and addresses the historical and current status of the fish and wildlife in the San Joaquin Valley. It also addresses the agricultural drainage impact on fish and wildlife and proposes suggestions for resolving the problems in the San Joaquin Valley.

The fish and wildlife habitat in California has drastically declined as a result of development of agricultural land. The present acreage of natural fresh water lakes, wetland and riparian habitats are 1%, 15%, and 7% of their historic extent, respectively. The acreage of agricultural drainage evaporation ponds and agroforestry plantations irrigated with drainage water are 7,000 and 500 acres, respectively. Approximately 190,000 acres of land in the Valley are managed for the benefit of fish and wildlife. The water supply needs of the wetlands is about 440,000 acre-feet/year and the firm water supply is about 30% of needs.

Toxic trace elements of concern in the agricultural drainage waters are: arsenic, boron, cadmium, chromium, copper, lithium, manganese, mercury, molybdenum, nickel, selenium, strontium, uranium, vanadium, and zinc. In addition to trace elements, there is evidence of adverse effect of agricultural drainage water to the eggs of aquatic birds nesting in or over the water. Stripped bass and chinook salmon exposed to agricultural drainage water free of trace elements (reconstituted water) experienced toxicity effects.

There is concern over discharge of the drainage water from the west side of the San Joaquin River Basin into the San Joaquin River. The drainage water previously used in wetlands in the Grasslands area is being discharged to the San Joaquin River, issuing greater stress on the River beneficial uses. There is also concern over the bioaccumulation of trace elements in the food-chain organisms in evaporation ponds in the Valley. Studies in 1987 and 1988 indicated significant adverse effects in birds using evaporation ponds. Agroforestry plantations irrigated with water containing trace elements may pose a threat to wildlife using these sites.

The authors recommend that the 242,000 acre-feet/year of water freed (becoming available in year 2000 as a result of land retirement, ground water management, and source control) as a result of implementation of the SJVDP Recommended Plan should be allocated to fish and wildlife needs in the Valley.

D. Agricultural Drainage Treatment Technology Executive Summary [31].

A review of the major treatment methods considered by the SJVDP is briefly discussed in this report.

The biological treatment technologies generally use an anaerobic process to reduce oxidized forms of selenium to elemental selenium that can be removed by solid separation technologies. However, nitrates have been identified as inhibitors of this reduction process. Recently, microbial volatilization of selenium from both soil and water have been tested. This process is not very fast and requires intensive management of the system for the volatilization process to be efficient. The advantage of this process is conversion of selenium to volatile form which does not need costly disposal. The microbial removal of selenium requires carbon



source which can be a major cost factor in treatment of agricultural drainage waters. The amendments needed for selenium volatilization from water may result in eutrophication of the pond systems.

The physicochemical processes investigated for removal of selenium from drainage water are adsorption of selenium on iron filings, chemical reduction of selenium, ion exchange, and reverse osmosis. Iron filings is being tested in the Valley. Chemical reduction of selenium with ferrous hydroxide has also been tested. Nitrate and oxygen are identified as inhibitors of this process. Reducing levels of nitrate and oxygen are required for the process to be efficient which affects the cost effectiveness of the project. The ion exchange process needs more research to formulate resins that are selective to selenate. Sulfate competes with selenate in ion exchange process. Reverse osmosis has been field tested for selenium removal. This process is very efficient for selenium removal but drainage water pretreatment is necessary and boron may remain high in the treated effluent. The market value of processed water for agriculture depends on the boron level left in water. The process is very expensive.

None of the existing treatment technologies are capable of consistently producing treated water with selenium concentration of less than 10 ppb.

Disposal of waste created from treatment plants is an important element of the treatment scheme. There is not a uniform cost parameter to compare different treatment technologies. It is also recommended that, in the future, other drainage issues besides selenium should be addressed. The salt accumulation in the Valley is discussed and adopting a policy for attaining and maintaining the mass balance in the Valley for a productive agriculture is suggested.

E. Selected Trace Elements in Biota of the San Joaquin Valley: A Screening Level Public Health Evaluation [32]

In this work, a screening level of evaluation is made of selected trace elements (cadmium, chromium, copper, manganese, nickel, and zinc) in fish and wildlife of the San Joaquin Valley. Among these six elements chromium, copper, manganese, and zinc are required for human nutrition. Cadmium and copper are the only trace elements studied that were found at elevated levels in bird liver tissue.

F. Water Pricing Policies and Institutions for Regional Regulation of Drainage Quality and Quantity [33]

A regional model is developed to assess the effect of policies aimed at controlling drainage quality and quantity. The model includes physical and economical submodels. The policies tested include constraints on water quantity, drainage discharge quantity, drainage quality, and acreage irrigated. The model is applied to a region in California. From this work it appears that a combination of policies are needed to maximize the regional income and minimize the regional drainage.

## **II. San Joaquin Valley Drainage Program Followup**

Following release of the final report, the SJVDP Policy and Management Committee, consisting of the directors of the five cooperating agencies (USBR, USGS, USFWS, DWR, and DFG), established the San Joaquin Valley Drainage Program Followup (Followup Program). The Followup Program member agencies are USBR, USGS, USFWS, DWR, DFG, State Board, EPA, the California Department of Food and Agriculture (CDFA), and DHS. The purpose of the Followup Program is to develop a strategy for implementation of the recommended measures outlined in the final report. The strategy will describe the actions needed, responsibilities of all participating agencies, and funding sources. The Followup Program final report due in December 1991 will address the implementation strategy, long-term monitoring program to track the effectiveness of the recommended measures, and a plan for management of SJVDP database.

## Chapter 4 State Department of Water Resources

### I. Drainage Reduction Program

The following are DWR ongoing drainage reduction projects:

#### A. Tiered Water Pricing

The tiered water pricing has been studied for the past two years in Broadview Water District. The purpose of this program is to encourage water conservation and drainage reduction through water pricing. Results indicate that during 1989-1990 irrigation seasons the volume of drainage water decreased approximately 7% compared to the previous three year average as a result of increase in price of irrigation water.

#### B. Water Conservation Coordinator

The purpose of this activity is to provide growers with information on water conservation techniques. The water conservation coordinator presents seminars to growers and publishes articles in the local news papers.

#### C. Agroforestry Projects

Utilizing the Assembly Bill 444 funds DWR is funding agroforestry projects in the San Joaquin Valley. DWR placed a proposal for 319(h) grants to the State Board for agroforestry plantation. The purpose of this project is to use trees to intercept lateral ground water movement.

#### D. Emerging Irrigation Technology

Four irrigation techniques are compared in the west side of the Valley. Subsurface irrigation, least energy precision application, improved furrow, and traditional furrow irrigation methods are experimented on a 160-acre field. This project was initially funded by the State Board and DWR for a three-year duration. DWR has funded this project for an additional three years. The results from the first two years indicate that subsurface irrigation has the lowest net cost. The water use efficiency was the highest for subsurface irrigation.

### II. Evaporation Pond Investigations

DWR evaporation pond studies address the following subjects [34]:

#### A. Pond Ecology

The purpose of this work is to investigate the intra-cell variability of selenium in invertebrates in evaporation ponds. This work is being conducted by DFG and a report is expected in August 1991. In another study, DWR supports investigating the possibility of applying pesticide demolin to minimize invertebrate population and break up the food chain in the ponds.

B. Selenium Speciation and Cycling

The purpose of this work is to investigate the forms of selenium that are taken up by plants and invertebrates in the ponds.

C. Wildlife Impact Studies

This study evaluates the levels of selenium in the birds using the ponds. DFG is conducting the study and a report is expected in 1992.

D. Development of Pond Management and Disposal Alternatives

This study is designed to develop pond management alternatives to minimize birds use of the ponds. Alternative ways of hazing is being studied. Cost effectiveness of methods of hazing waterfowl from ponds are being studied. Acidification of pond water to break up the food chain is also under study. A report is expected in November 1992.

E. Pond Research Facility

DWR is developing a pond research facility in cooperation with pond operators to study pond management methods.

F. Offsite Compensation and Mitigation

The purpose of this work is to determine the needs and evaluate alternative methods of providing offsite compensation and mitigation.

G. Cumulative Impact Studies

The purpose of this work was to evaluate beneficial/detrimental impacts of agricultural evaporation ponds on waterfowl. A draft technical report (TR) was prepared for DWR by a group of consultants in March 1991 [35]. The TR was prepared in response to DFG requiring that the cumulative impacts of evaporation ponds should be evaluated for issuing Waste Discharge Requirements (WDRs) for the ponds. Regional Water Quality Control Boards issue or revise WDRs. Furthermore, California Environmental Quality Act requires that a cumulative impact study on wildlife be performed prior to issuing WDRs. This report addresses the impacts on wildlife, suggests mitigation measures, and research needs.

The agricultural drainage water totalling 30,000 acre-feet from about 59,000 acres of land in Tulare Lake Basin is discharged to about 7,000 acres of evaporation ponds. The significant adverse impacts resulting from evaporation ponds are reduced egg hatching success and teratogenesis (embryo deformities) in water birds breeding at some evaporation ponds in the San Joaquin Valley. The size of the area adversely affecting waterbird reproduction may increase as a result of increase in

concentration of toxic trace elements in ponds and/or increase in pond area due to new pond construction. The beneficial effects of evaporation ponds are also discussed. Clean ponds provide safe breeding habitat for birds and wintering and migratory waterbirds benefit from the ponds also. The report concludes that available techniques are not capable of completely eliminating adverse impacts. The mitigation plan outlined in the report includes reducing bird use, reducing food accessibility, controlling aquatic production through use of pesticides, and compensating for the bird reproductive loss as a result of evaporation ponds impacts. The mitigation plan uses the DFG interim management guidelines that all pond operators are required to follow. DFG guidelines are designed to minimize the impact with existing pond management techniques while evaluation and improvement are being made.

### **III. Agricultural Drainage Monitoring**

DWR has been monitoring agricultural drainage in the San Joaquin Valley as a part of the department's agricultural drainage investigation since 1963. Drainage monitoring is conducted in a central area in Fresno county and the southern area which includes parts of Kings, Kern and Tulare counties. DWR published its 1990 annual drainage monitoring report in July of 1990 [36]. Several trace elements are among the constituents measured in drainage water from the monitoring areas. 1987 data indicates that chromium, copper, iron, manganese, mercury, and selenium levels exceeded the aquatic life criteria for these elements. Eleven other trace elements analyzed for were found at low levels. Average concentration of boron measured in drainage waters from central and southern areas were 16.8 and 24 mg/L, respectively.

DWR has a monitoring program for the lower part of the San Joaquin River and the Delta [37]. Selenium is the trace element analyzed for in the water samples collected from the area which extends from Vernalis to the H. O. Banks pumping plant.

### **IV. Drainage Treatment and Disposal**

DWR is establishing a demonstration plant for anoxic bacterial selenium removal process [38]. This project will be conducted at the Agricultural Drainage Research Facility to be established at Adams Ave near Tranquility. This facility is planned to test agricultural drainage management alternatives on a pilot scale. The purpose is to integrate various management methods. The anoxic bacterial selenium removal process is designed to investigate anoxic biological selenium removal using two reactor configuration. The effluent from the plant will be disposed of through agroforestry or land spreading. The biomass will be disposed of by above ground drying beds and volatilization. Participants are California State University Fresno (CSUF), University of California, Davis (UCD), DWR, Westland Water District (WWD), and USBR. The land is leased from WWD. DWR and USBR provide funding for the facility.



## Chapter 5 California Department of Food and Agriculture

CDFA is the lead agency to study the agroforestry concept in California [39]. The agroforestry farming system depicts a farm where fresh water is used for irrigation of salt sensitive crops and trees. The drainage waters containing selenium from this irrigated field will be used for irrigation of higher salt tolerant crops and trees. The drainage waters from this field will then be used to irrigate more tolerant trees such as eucalyptus. Drainage water from eucalyptus trees will be used for irrigation of halophyte plants. The drainage water from halophytes will be disposed of by evaporation ponds, or will be treated in drainage treatment facilities. The agroforestry concept provides for reuse of drainage water and reduction of volume of drainage water to be disposed of or treated.

The potential of agroforestry to provide for productive use of drainage water, evaporation of drainage water, management of salts and selenium, control of water table, diversification of crops, and improved ecology of the farms is being studied by several agencies.

### I. Research Projects [40]

#### A. Selection and Propagation of Trees

Two salt tolerant trees (eucalyptus and casuarina) are being studied in the saline-high water table areas of western Fresno, Kings, and Kern counties. The superior trees are being selected for planting.

#### B. Intersection of Wildlife and Agroforestry

Studies by SJVDP has indicated that the agroforestry plantation produce habitat for birds and small mammals and potential contamination of wildlife could occur at these plantations. DFG is conducting a study to investigate the wildlife contamination at these plantations.

#### C. Salt and Water Balance in an Agroforestry System

A study at the Murrieta Farms in the western San Joaquin Valley is designed by UCD researchers to investigate the salt and water balance in the soil profile in an Eucalyptus plantation. Salinity, selenium, and boron accumulation in the soil profile was observed during 1987-1990 irrigation seasons. Studies at Murrieta Farms [40] indicate that electrical conductivity of drainage water from the eucalyptus plantation was about 30 ds/m compared to 10 ds/m for the applied drainage water. Selenium concentration in wood and leaf was less than 200 and 900 ppb, respectively. Accumulation of salts and boron in soil profile and its toxicity effects on agroforestry plants are also being studied. The accumulation is apparently reaching the tolerance limit of eucalyptus for boron and salinity toxicity limits. Hence, leaching or careful management of the agroforestry appears to be essential to prevent damage to plants.

#### D. Testing of Halophyte Plants

Salt tolerant halophytes are being irrigated by the saline drainage water collected from the eucalyptus trees. Halophytes have higher salt tolerance than eucalyptus trees and they also absorb higher amounts of elements from soil. Atriplex, saltgrass, wheatgrass, and tall fescue are being tested. Halophytes can tolerate salinity of up to 50 ds/m and can use up to three feet of water per year. Use of halophyte plants as forage crops are under study.

The accumulation of selenium in the leaves of agroforestry plantations and the potential risk of uptake of trace elements by birds and wildlife exists at the agroforestry plantations [41].

Other projects are: economics of agroforestry, agroforestry biomass utilization, study of actual evapotranspiration of agroforestry plants, marketing of biomass, and monitoring of soil, water, and plant tissues that are underway by different agencies.



## Chapter 6 University of California Salinity Drainage Task Force

The University of California Salinity Drainage Task Force (Task Force) was formed in 1985. The Task Force's mission is to develop, interpret, and disseminate research results relevant to salinity, drainage, and toxic trace elements in the San Joaquin Valley. The Task Force published its annual Technical Progress Report in September of 1990 [42]. The Task Force accomplishments and the results of 1989-1990 research projects are presented in the annual report. The 1989-1990 research activities were focused on the following subjects: (1) hydrology and transport of salts and trace elements; (2) trace elements chemistry and microbiology; (3) bioavailability and bioaccumulation of trace elements in the food chain; and (4) salinity, selenium, drainage, and irrigation management options.

The 1990-1991 research subjects to be addressed by the Task Force researchers are (1) reuse of saline drainage and ground waters on crops grown in the west side of the Valley, (2) shallow ground water management and flow reductions and its impact on reduction of total dissolved solids and toxic trace elements, (3) economic and institutional aspects of drainage water management alternatives, (4) competitive assimilation of potentially toxic trace elements (selenium, arsenic, molybdenum, boron, uranium, and vanadium) and partitioning in food crops grown under saline environments, and (5) microbial transformations and redox reactions of trace elements (oxyanions) in saline, water-logged soils. A brief description of results from selected 1989-90 research projects follows [42].

### I. University Research Projects

#### A. Modelling Shallow Water Table Management: Simulation and Validation

The purpose of this project was to simulate amount of water and salt contribution to the crop root zone under water table management and determine the short and long-term implications of saline water table management. The authors have modified an existing model to simulate crop production under saline water table conditions. They conclude that agreement between the model simulations and limited experimental data is very good. The results suggest that high yield can be maintained for several years without drainage if proper irrigation is practiced. This model can be used to simulate various scenarios and investigate the impact of management practices.

#### B. The Effect of Oxidation-Reduction Conditions on Transformation of Selenium in Soils of the Western San Joaquin Valley

The purpose of this project is to investigate oxidation-reduction transformation of selenium in soils in the presence of nitrate and manganese. This study suggests that nitrates can inhibit selenate reduction. It also confirms that selenate is reduced after nitrate reduction has begun but before manganese reduction is complete.

#### C. Microbial Mediation of Selenium Oxidation and Reduction

The purpose of this work is to investigate microbial oxidation of selenium. The study findings suggest that oxidation of selenium sulfide

is microbially mediated. The product of the oxidation process appears to be selenite. However, the authors do not find evidence for microbial oxidation of iron selenides. Furthermore, sulfur may have a role in biochemical reactions of selenium and in the absence of adequate sulfur, microbial processes of selenides may be retarded.

D. Distribution and Sources of Uranium and Associated Trace Elements in Selected Waters of the San Joaquin Valley of California

This project involved collecting water samples from shallow and deep water wells from near the agricultural drainage evaporation ponds in the San Joaquin Valley. The water samples were analyzed for twenty trace elements. Elevated concentrations of selenium, uranium, boron, vanadium, arsenic, and molybdenum were observed. Selenium values ranged from less than 1 to 940 ppb in shallow well water samples. Concentration of arsenic in 28 samples ranged from 1 to 147 ppb. Other trace elements were measured above the detection limit. Concentration of uranium in two shallow well water samples was 2600 and 3300 ppb.

E. Selenium Volatilization in Animal and Human Food Crops Grown in California

The objective of this work is to compare the rate of selenium volatilization for 15 animal and food crops, and investigate the selenium uptake, partitioning, and volatilization in plants grown in high sulfate soils. Carrot, broccoli, cabbage, tomato, cucumber, barley, alfalfa, and cotton volatilized selenium in hydroponic media. The authors found that sulfate suppresses selenium volatilization by plants studied. Rice and broccoli were found the highest selenium volatilizers in this study.

F. Microbial Volatilization of Arsenic From Soil and Water

The objective of this work is to develop a bioremediation process for arsenic. The authors are investigating the use of a bioreactor to volatilize arsenic and trap the gas in a charcoal trap assembly.

G. A Genetic and Biochemical Approach to Microbial Purification of Agricultural Waste Waters

The purpose of this study is to isolate selenate/selenite metabolizing microorganisms that could be used to remove selenium from agricultural drainage waters containing nitrates. The study results indicate that selenate reduction takes place by a selenate respiring microorganism, *Pseudomonas* Sp. The study also indicates that nitrate does not inhibit the reduction of selenite, formed as a result of selenate reduction, to elemental selenium. This microorganism may be used for selenium removal in biological reactors. The authors are testing the results in a biological reactor.

H. Determination of the Toxicity and Bioaccumulation Potential of Agricultural Drainage Water Contaminants in Aquatic Food Chain

Transformation and biochemical speciation studies of selenium indicate that selenium is transformed by algae to selenoaminoacids which are then incorporated into proteins. The effect of selenium on aquatic invertebrates indicates two patterns. In a selenium feed study *Daphnia magna* showed no selenium accumulation and no toxicity while midge exhibited elevated level of selenium and reduced growth rates.

The Task Force is preparing a five-year summary report which includes research topics addressed and accomplishments during 1985-1990 period. This report is expected in mid or late 1991.



## Chapter 7 Related Programs

### **I. U.S. Department of Interior (DOI) National Water Quality Program**

DOI developed a program in 1985 to respond to the irrigation induced water quality problems in the western United States [43]. The DOI program included addressing irrigation induced water quality problems in the DOI irrigation and drainage facilities, National Wildlife Refuges, and other migratory bird/endangered species management areas receiving DOI water. DOI plan involves five phases:

- A. Site identification
- B. Reconnaissance investigations
- C. Detailed studies
- D. Planning
- E. Remediation

To date, 22 sites in 13 states have been identified as having potential for irrigation induced water quality problems. Six sites are located in California. One of them, the lower Colorado River, has been removed from the process and is under long-term monitoring. Five other sites are: (1) upper Sacramento River where the reconnaissance phase is complete and planning phase has started, (2) Salton Sea, (3) Tulare Lake where detailed studies have been completed and the remediation phase will follow, (4) San Joaquin Valley where the planning phase is complete and implementation strategy is being prepared, and (5) Kesterson Reservoir where remediation is underway. DOI has published several reports on these activities [44-51].

### **II. U.S. Department of Agriculture (USDA) Water Quality Program (President's Water Quality Initiative) [52]**

The objectives of this program are to determine the relationship between agricultural activities and ground water quality and develop agricultural management strategies that protect the quality of surface and ground waters. This program emphasizes on educational and technical assistance to minimize water contamination by agrichemicals, research and development of agricultural practices that reduces water quality impairment, and development of a database to be used to assess the effect of agricultural practices on water quality and the effect of various policies for reducing water quality impacts. Eight USDA agencies, EPA, and DOI and the Department of Commerce are the cooperating agencies in this program.

### **III. U.S. Bureau of Reclamation San Luis Unit Drainage Program**

San Luis Unit Drainage Program (SLUDP) objective is to identify and implement a long-term drainage plan to meet the drainage needs for the San Luis Unit Service area of the Central Valley Project through year 2007. The SLUDP area includes Westlands, Broadview, Panoche, Pacheco, and part of San Luis water districts. USBR published a Preliminary Alternatives Description report in 1990 [53]. The report outlines three alternatives: (1) treatment (agroforestry, thermal evaporation and evaporation ponds) and disposal (discharge to San Joaquin River and landfills), (2) source control (ground

water management, drainage reduction, and alternative land use) and treatment and disposal, and (3) source control, incentive programs, and treatment and disposal. USBR will release Alternative Plans Report and a draft environmental impact statement on proposed actions to manage drainage waters from the SLUDP study area in the near future. The final drainage plan is due December 31, 1991.

#### **IV. U.S. Department of Interior San Joaquin River Basin Resource Management Initiative**

Established in 1989, the purpose of the Initiative is to prepare a Management Plan to identify process and resources needed to conduct studies and take necessary actions for environmental recovery in the San Joaquin River [54]. The Initiative focus is on water quality, fisheries and wildlife, and recreational issues. The Initiative workplan has a five-year time frame. The Initiative final work product is expected to identify opportunities to improve water quality-related aspects of the San Joaquin River System. The Initiative studies will address operation of water projects, potential for water conservation, water transfers, optimum location, and time of diversions. The lead agency for the Initiative is USBR.

#### **V. State Department of Water Resources San Joaquin River Management Program**

The California Legislature adopted Assembly Bill 3603 in 1990 [55]. The Assembly Bill established the San Joaquin River Management Program Advisory Council (Advisory Council) and the San Joaquin River Management Program Action Team (Action Team). The Advisory Council is developing a management program which identifies the actions that can be taken to benefit the beneficial uses of the San Joaquin River system. The management program will address ongoing studies relevant to the San Joaquin River, will identify problems, and recommend a series of priority actions and proposed funding sources. The Action Team serves as a work group to develop management program elements. DWR is the lead agency for this activity. The State Board and the Central Valley Regional Board participate in both the Advisory Council and Action Team.

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List of Acronyms

A	Acre
AB	Assembly Bill
AF	Acre Feet
ARS	Agricultural Research Service
BMP	Best Management Practice
BWD	Broadview Water District
CDFA	California Department of Food and Agriculture
CSUF	California State University-Fresno
DFG	Department of Fish and Game (California)
DHS	Department of Health Services (California)
DOI	Department of Interior (US)
DOP	Drainage Operation Plan
DWR	Department of Water Resources (California)
EC	Electrical Conductivity
EPA	Environmental Protection Agency (US)
FY	Fiscal Year
LEPA	Least Energy Precision Application
MA	Million Acre
MAF	Million Acre Feet
NWR	National Wildlife Refuge
PPB	Parts Per Billion
PPM	Parts Per Million
SJVDP	San Joaquin Valley Drainage Program
SVS	Selenium Verification Study
TDS	Total Dissolved Solids
UCD	University of California Davis
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey
WDR	Waste Discharge Requirement
WPCL	Water Pollution Control Laboratory (DFG)
WQ	Water Quality
WWD	Westland Water District
WY	Water Year



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