Agricultural Drainage in the San Joaquin Valley

A Gap Analysis

October 2002

San Joaquin Valley
Drainage
Implementation
Program

DRAFT

Agricultural Drainage in the San Joaquin Valley

A Gap Analysis

October 2002

Prepared by: Clinton Williams and Manucher Alemi

Assisted by : Dave Koller (formerly with DWR) , Jose Faria (DWR), Mike Delamore (USBR), Matt Reeve (CDFA), Ron Rowe (CALFED), and Wayne Verrill (SWRCB)

San Joaquin Valley Drainage Implementation Program

Agricultural Drainage in the San Joaquin Valley A Gap Analysis

The San Joaquin Valley Drainage Implementation Program
October 8, 2002

California's San Joaquin Valley is one of the world's most vital and productive farming areas. The westside of the San Joaquin Valley is a fertile yet arid landscape where commercial agriculture is viable with supplemental irrigation and soil fertilization. The importation of surface water and use of groundwater for irrigation as well as fertilizers results in the addition of salts to agricultural lands in addition to naturally occurring saltThe leaching requirement to remove salt from the crop root zone to maintain soil quality and productivity results in the deep percolation of applied water. Agricultural lands of the westside SJV are underlain by a low permeability clay layer without adequate drainage, causing a shallow water table to rise toward the soil surface. Waterlogging of the crop root zone and evapotranspiration of soil water from the shallow water table results in the accumulation of salts and potentially toxic trace elements in the crop root zone and shallow groundwater. High concentrations of naturally occurring trace elements in drainage water, such as selenium may pose a hazard to fish and wildlife when discharged to the surface water bodies. Nutrients from drain water may also contribute to algal blooms and depletion of dissolved oxygen in surface waters, organic carbon may also lead to BOD imbalance and dissolved oxygen depletion, in addition organic carbon as disinfection by-product precursors, nitrate and other trace elements may further degrade quality of water for drinking purposes.

The Westside of the San Joaquin Valley includes the San Joaquin River Basin and the Tulare Lake Basin with 2.4 million acres of mostly irrigated agricultural land. Historical drainage discharged to the San Joaquin River was about 55 thousand acre-feet (TAF) per year from an estimated 50,000 acres of land with installed subsurface drain. The Tulare Lake Basin at the southern end of the Valley has no natural drainage outlet and annually discharges 15 TAF of drainage water to evaporation ponds. In areas without installed subsurface drains and no or inadequate natural drainage, salts accumulate in the groundwater aquifer and the water table may rise over time resulting in water quality degradation and water table problems.

Federal and State agencies have long recognized the need for proper drainage. In 1960 congress authorized construction of the San Luis Unit of the Central Valley Project. The Bureau of Reclamation was authorized to either participate with the State in a master drain project or construct the San Luis Interceptor Drain to serve the drainage needs of the San Luis Unit. The project was revised in 1962 to a concrete-lined canal that would drain 300,000 acres. In 1964, the plans included a flow regulatory reservoir (known as Kesterson) to control discharge to the Delta and to minimize the size of the drain facility. The State participated initially in joint planning of the master drain but withdrew in 1964 due to lack of funding for the program.

By 1975, an 82-mile segment of the Drain (Laguna Avenue in Fresno County to Kesterson Reservoir) and 120 miles of collector drains were completed. The first 1,280 acres of a planned 5,800-acre regulating reservoir complex was to be used for wetland habitat. When construction was interrupted in the mid-1970s because of federal budget constraints and environmental concerns, the Bureau decided to use Kesterson Reservoir to store and evaporate drainage water until the Drain to the Delta could be completed. In 1977 congress authorized funding to continue constructing the distribution and collection system for the San Luis Unit. Construction began and drainage water discharge from Westlands water District to Kesterson initiated in 1978.

In 1983, deformities and deaths of aquatic birds were discovered at Kesterson. This was attributed to selenium toxicity originated from drainage water and work on completion of the Drain never resumed.

In 1984 in response to the findings at Kesterson Reservoir, the San Joaquin Valley Drainage Program (SJVDP) was established to investigate drainage and drainage-related problems and to develop possible solutions. SJVDP initially investigated all drainage management options including out-of-valley drainage disposal. However, due to strong objections from environmental interest groups and coastal communities, SJVDP adopted a decision to limit studies to in-valley drainage management measures. In 1990, the SJVDP released *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley,* also known as the Rainbow Report, to manage drainage problems from 1990 to 2040. The Rainbow Report recommended following measures: source control, drainage reuse, land retirement, evaporation ponds, discharge to the San Joaquin River, groundwater management, provision of water supplies for fish and wildlife and institutional changes. It also recommended continued research on drainage water treatment. The 1990 Plan, in part, states, "Implementation of the recommended plan would allow maintenance of a salt balance in the plant root zone. This is in contrast to future-without conditions in which a salt balance could not be maintained and would lead to soil salinization. Implementation of the recommended plan would maintain the water levels below the root zone. How long can such a strategy work? The Drainage Program's answer is based on the assumption that the potential to continue to store salts in the subsurface will be approaching exhaustion when subsurface water is saturated with salts in the semi-confined aquifer that exceed 2500 ppm. When that water quality is reached, it is theorized, it will also have contributed to increased degradation of the confined aquifer. Assuming that growers will not pump that water, the water table will rise again and it will be difficult to manage the salt in the root zone." The increased degradation of the aquifer affects beneficial uses of the groundwater and potentially surface water bodies and its beneficial uses.

Although the 1990 Plan was based on managing the problems in-valley for several decades without exporting drainage water and salts to the ocean, it also stated that, "ultimately, it may become necessary to remove salt from the Valley". The Rainbow Report stated, "…Several of them [management actions], fitted together into a coordinated, comprehensive plan for action, could be effective in managing drainage problems. The mix of options will have to be varied to accommodate local and regional differences in drainage problems and opportunities for solution". The Rainbow Report also determined that "…Management of drainage problems in the manner presented in the recommended plan tends to enhance near-term (up to 50 years) protection of soils and off-site impacts of drainage discharges, while continuing to diminish the life of westside aquifers". It was also concluded that the implementation of the management plan would provide "…the preliminary steps that would likely be needed when salt removal from the valley becomes necessary and feasible. These steps include integrated in-valley systems to collect and reduce the volume of drainage water, accompanied by containment and control of contaminants, such as selenium".

In 1991, four State and four Federal agencies signed a Memorandum of Understanding and agreed to coordinate budget and programs to help implement the 1990 Plan. The MOU created the San Joaquin Valley Drainage Implementation Program (SJVDIP). SJVDIP is lead by a Management Group consisting of member agencies' management representatives.

In 1992, Sumner Peck Ranch, Incorporated, et al. brought suit in U.S. District Court, Eastern District of California, against the Bureau for failure to complete the Drain as authorized by federal law. Firebaugh Canal Company and Central California Irrigation District located in the Grasslands subarea joined Sumner Peak Ranch in the suit.

On December 2, 1994, Judge Oliver W. Wanger found that the Secretary of the Interior, through the Bureau, made a policy decision not to complete the Drain, thus violating the federal San Luis Act, and constituting an action unlawfully withheld and causing irreparable injury to the plaintiffs. Judge Wanger further ruled that no other provisions of federal or State law precluded the possibility of completing the Drain. The Bureau was ordered to apply to SWRCB for a discharge permit.

The Bureau appealed the court order and in November 2000 the Ninth Circuit of Appeals ruled in favor of the Plaintiffs and ordered "…the Government to, without delay, provide drainage to the San Luis Unit". The Bureau began the San Luis Drainage Re-Evaluation process in 2001. As part of the process the Bureau will determine a number of drainage alternatives, refine and evaluate those alternatives and then propose preferred alternatives for further investigation and permitting. The preferred alternatives are scheduled for adoption by December 2002.

In 1999, SJVDIP conducted a review of key components of the SJVDP recommended plan and reports were prepared. Technical committees evaluated the 1990 Plan recommendations (measures) as well as salt utilization as a new component of solution to the drainage problems in the San Joaquin Valley. The technical committees review process did not address increased water deliveries to wildlife refuges or the institutional measures needed. These actions proposed by the Rainbow Report were policy actions and therefore not subject to review by the technical committees.

In October 2000, the SJVDIP Management Group adopted a Drainage Management Strategy outlining a process to pursue implementation of the recommended in-valley solutions. Farmers and water districts within the Valley have adopted various irrigation improvements and drainage reduction measures to manage salts and trace elements in response to regulatory requirements to protect environmental resources. These actions have resulted in significant reduction in the volume of drainage water discharged to the San Joaquin River (from 57 TAF in 1990 to about 30 TAF in 2000). Acreage of and discharge rates to evaporation ponds have also been reduced, since selenium induced teratogenesis in wildfowl embryos was found. For example, the evaporation pond acreage reduced from about 6 000 acres in 1990 to about 4 000 acres in 2000. The irrigation and drainage management measures and some fallowing and land retirement have been the primary mechanisms for water conservation and reduction of contaminant loads to water bodies in the region. These measures coupled with separation and future safe disposition of salts from the root zone and groundwater aquifer could result in sustainable soil and water quality.

To implement the 2000 Drainage Management Strategy, SJVDIP has formed an Informal Drainage Advisory Committee to seek input from stakeholders on priority drainage management actions. SJVDIP Management Group decided to develop the list of drainage management actions recommended for each drainage management option by the Ad Hoc Coordination Committee and conduct a gap analysis (that is- what have we accomplished and what remains to be accomplished?). Table 1 presents status of the drainage management options recommended by the 1990 Plan and the 2000 AHCC Report and presents opportunities and constraints for implementation.

Appendix A consists of separate gap analysis reports for each of the following drainage management measures recommended by the 2000 AHCC Report: Source Control, Drainage Reuse, Drainage Monitoring, Evaporation Ponds, Drainage Treatment, River Discharge, Salt and Selenium Utilization, Land Retirement, and Groundwater Management. Each drainage management measure gap analysis report contains specific recommended actions. For each action, projects undertaken and planned since 2000; and constraints and opportunities to move forward are presented. The gap analysis is intended to provide information to decision makers to direct resources to programs, actions, and areas where progress is most needed to help solve drainage and related problems in the San Joaquin Valley.

Summary of Implementation Status of SJVDP Recommendations/Accomplishments, Constraints and Opportunities

Drainage Management Option (recommendation)	Drainage Management Objectives, Status, and Accomplishments	Constraints and Opportunities
Source Control-irrigation management and irrigation system design improvements	SJVDP recommended source control on 329,000 acres by 2000. SJVDP recommended was to improve on-farm water conservation and source control on all irrigated lands and reduce deep percolation on lands having drainage problems by 0.20 to 0.35 acre-feet per acre per year (on the average) as soon as possible. DWR and USBR should increase their work with the university extension systems and water districts to demonstrate ways to improve the efficiency of irrigation water application and thereby reducing drainage volumes. Each water district should, by 1992, set objectives in their operation plans that would reduce deep percolation by the amounts stated above. State and Federal agencies should help local water districts accomplish their water conservation. The State of California should expand and intensify its program of on-farm water conservation to focus especially on demonstrating alternative source control measures on drainage-problem lands. SJVDIP agencies have provided substantial funding and technical support towards improving source control. Growers and districts, in turn, have made substantial investments and gains in implementing improved source control. Source control objectives have been achieved or exceeded over large areas with significant reduction in deep percolation or drainage volume in dry years. DWR and USBR should pursue more demo projects. Only a few districts have included the drainage reduction goals in their plans, but none have incorporated the 0.2 to 0.35 af/a in their operation plans. DWR and USBR have on-farm water conservation and drainage reduction program.	Improved source control has been necessitated by sustained water supply shortages since 1990 as well as by the need for improved drainage management and incentive programs to implement irrigation management and system improvements. But the goal of 0.20-0.35 af/a reductions has only been met in extremely dry years. Opportunities exist for further water conservation and drainage reduction through incentive programs. Some districts have policies that limit pre-irrigation to 8", which reduces drainage. Source control results in increased salt and selenium concentrations and the condition warrants continued monitoring. Limited funding has curtailed projects. CALFED water use efficiency program can provide the means for accomplishing this goal. Implementation of Efficient Water Management Practices is intended to help improve on-farm irrigation efficiency.

Drainage Management Option (recommendation)	Drainage Management Objectives, Status, and Accomplishments	Constraints and Opportunities
Drainage Reuse- Reuse of drainage water on successively more salt tolerant crops reduces volume of drainage and saves water.	SJVDP recommended drainage reuse be implemented in 260,000 acres of tile-drained farmland with 23,000 acres of halophytic crops by 2000. SJVDP recommended installing subsurface drains. Recommendations of installing drains have not been implemented. Demonstration projects are testing the SJVDP recommended concept of irrigating salt tolerant trees and halophytes to reduce the volume of drainage water requiring disposal. Significant progress has been made in selection of trees and halophytes, and design of reuse systems. Eucalyptus trees have been successfully used for intercepting subsurface lateral drainage waters.	Installation of subsurface drains is essential for removal and control of drainage waters. Installation should be promoted as long as drainage is managed in compliance with CVRWQCB requirements and objectives. The removal of excess salts and its disposal or utilization is essential for a sustainable reuse system. Also avoiding wildlife and environmental impacts of discharging brine to surface impoundments are essential for operating a complete drainage reuse system. Senate Bill 1372 may allow for drainage reuse systems with specific design to avoid these impacts.
Monitoring- Measurement of soil, water, and biota in the Valley.	SJVDP stated that successful program implementation depends on long-term, systematic monitoring both the problems and the progress. Also water supply and drainage districts should participate in joint coordinated programs to monitor the quality and volume of drainage water in the collection, treatment and disposal systems. SJVDIP developed a plan for extensive monitoring of water, soil, and biota. DWR monitors drainage sumps in the Valley. Local agencies that discharge drainage water to ponds or the River are under waste discharge requirements and prepare monitoring plan and reports to the Central Valley Regional Water Quality Control Board (CVRWQCB). In Grasslands area there is a coordinated regional monitoring program in existence. But other monitoring such, as the effects of corrective actions on soil salinity and crop productivity are not being conducted.	Existing monitoring programs should be continued. A coordinated San Joaquin Valley Monitoring Plan should be developed in cooperation with CALFED Ecosystem Restoration Program, Drinking Water Quality Program, and Water Use Efficiency Program. Current programs are limited by inadequate funding. Groundwater quality needs to be more closely monitored. Sediment sampling in relationship to Selenium may be more indicative of bioaccumulation and in some cases ecotoxicity risk than water column concentration alone and could be emphasized in any future "biota/ecosystem" assessment program/project.

Drainage Management Option (recommendation)	Drainage Management Objectives, Status, and Accomplishments	Constraints and Opportunities
Evaporation Ponds- Surface impoundments to discharge drainage water for evaporation.	SJVDP recommended construction of 2,600 acres of modified evaporation ponds in conjunction with drainage reuse systems by 2000. CVRWQCB has required pond operators to modify evaporation ponds (e.g., steeper interior slopes, remove interior windbreaks, remove tires to stabilize slopes, etc.). Pond modifications have been implemented by pond operators. Alternative and compensation habitat and demonstration projects have been established and are providing valuable information on mitigating habitats. No new evaporation ponds have been established.	Acreage of operating evaporation ponds has decreased from about 6,000 acres in 1990 to about 4, 000 acres. Reduction in evaporation pond acreage has occurred due to costs of environmental mitigation. Evaporation ponds appear to be feasible when selenium concentrations are low. Mitigation costs are high. Short supply of suitable water for mitigation habitat remains a problem, and more studies need to be conducted on mitigation and compensation habitat needs. Accelerated-rate evaporation systems should be tested and environmental requirements, energy demand, and cost issues have to be addressed.
Treatment- Removal of toxic trace elements through physical, chemical and biological methods.	SJVDP recommended continued research on treatment methods. Laboratory and pilot-scale projects have demonstrated the ability to treat drainage water through anaerobic bacterial processes, wetland microbial volatilization and flow through reduction/oxidation channels to bioremediate selenium. Reduction of high selenium concentrations to less than 50 parts per billion has been achieved. A demonstration of complete drainage water treatment has been attempted using reverse osmosis. Membrane clogging has been a problem. Pretreatment may be necessary.	A full-scale drainage treatment system for selenium bioremediation has yet to be constructed and successfully operated. Efficiency, cost effectiveness, and disposability of extracted brine have not been established. Economic constraints and technical problems are yet to be overcome before complete treatment of drainage water is shown to be a feasible treatment option. Cost of brine disposal and disposal environmental constraints are major limiting factors. Continued funding to support research and implementation is encouraged.

Drainage Management Option (recommendation)	Drainage Management Objectives, Status, and Accomplishments	Constraints and Opportunities
River Discharge- Discharge of drainage to SJ River subject to water quality standards.	SJVDP recommended continued discharge of drainage into the River subject to water quality objectives set by the CVRWQCB. The Grasslands drainers are implementing the Grasslands Bypass Channel Project, which freed up interior Grasslands channels for conveyance of water suitable for wildlife habitat use and discharges the drainage water to the San Joaquin River. This Project improved water quality in the Grasslands area primarily by source reduction and drainage reuse. CVRWQCB's proposed schedule for compliance with the objectives is October 1, 2010.	Source control alone is not sufficient to meet water quality objectives in the San Joaquin River and sloughs. Compliance with CVRWQCB water quality objectives may require implementation of other drainage reduction measures. GAF are developing a long-term drainage management plan.
Salt Utilization- Use of salts and trace elements.	Salt utilization was not part of the recommendations of the 1990 Plan	Transportation and a ready market are the major obstacles to the utilization of salts accumulated in the Valley.
Land Retirement- Cessation of irrigation of lands having high water table, low productivity and high selenium.	SJVDP recommended voluntary retirement of 21,100 acres of problem lands by 2000. State and federal agencies are encouraged to provide assistance to districts to identify lands candidate for retirement. Develop guidelines for retirement of irrigated lands that have high selenium concentrations in shallow ground water and that are difficult to drain. The Central Valley Project Improvement Act and the San Joaquin Valley Drainage Relief Act have respectively enacted federal and State authorization to implement land retirement. USBR has initiated a land retirement program, but the retired lands are short of the 2000 target. Westlands Water District has worked with USBR to identify candidate lands for retirement. USBR has developed preliminary guidelines. WWD has also taken major steps towards to initiate its own land retirement program.	Land retirement remains a controversial and complex issue, opposed by some growers because of impacts on neighboring lands and local economies and the failure to resolve the drainage problem and sustain agriculture. Others are willing to retire lands that, combined with other measures, would solve drainage problems. Development of management plans for retired lands has not yet been realized. Federal funds for land retirement have been limited. State funds for land retirement have been withdrawn. Temporary land fallowing may provide an opportunity for drainage relief and for freeing up water. CALFED, SJVDIP agencies, and stakeholders should further develop subsequent land use change and water management planning strategies.

Drainage Management Option (recommendation)	**Drainage Management Objectives, Status, and Accomplishments**	**Constraints and Opportunities**
Groundwater Management- Pumping of shallow groundwater to lower the groundwater table.	SJVDP recommended groundwater management on 40,000 acres by 2000. State and federal agencies and districts should do joint planning to design pumping from semi-confined aquifer to lower water table. This later recommendation has not been pursued. Westlands Water District investigated implementation of groundwater management and found it to be infeasible. Neither WWD nor any other entity is implementing this concept by design.	Intentional quality degradation of the sub-Corcoran groundwater resource is viewed as counterproductive. Implementation constraints include: (1) difficulty in locating semiconfined zones with suitable quality water for irrigation and/or wildlife habitat use; (2) cost of high-density wells extracting from the low-water-yielding semiconfined zone; and (3) potential incompatibility with State Water Resources Control Board's nondegradation policy.
Fish and Wildlife State and federal agencies should plan the facilities for water delivery to wildlife refuges.	The U.S. Bureau of Reclamation should actively seek authority to reallocate 74,000 acre-feet of water annually from the Central Valley Project to replace drainage water used on wetlands before 1985. The USBR Action Plan has resulted in the delivery of level II supplies since 1992 and level IV supplies are purchased for delivery in 10% increments to get full allocation in 2002. Provide 20,000 acre-feet of water to the Merced River each October to attract migrating fish from drainage water discharging to the San Joaquin River. Has been accomplished by Merced Irrigation District fish flow releases.	The fish and wildlife water supply needs as defined in the 1990 plan have been mostly met.

Drainage Management Option (recommendation)	Drainage Management Objectives, Status, and Accomplishments	Constraints and Opportunities
Institutional measures	Use the Grassland Task Force water districts as the nucleus of a regional drainage entity to coordinate and jointly manage subarea-wide drainage problems. Grassland Area Farmers organization has been formed. Develop a formal association of water districts (built around the existing Tulare Lake Drainage District) for coordinated and joint management of sub-area-wide drainage problems. An association of pond operators in the Tulare Lake Basin has been formed. (Central Valley Agricultural Evaporation Pond Operators, CVAPO). However, their function doesn't include joint management of sub-area-wide problems.	Drainage organizations can play a significant role and should be encouraged. Also, encourage local entities to implement education and outreach programs focused on BMPs to increase water use efficiency and reduce source loads. Financial assistance may be available from Prop 13 SWRCB/CALFED Non-point Source Pollution Prevention RFP's.

Drainage Management Option (recommendation)	**Drainage Management Objectives, Status, and Accomplishments**	**Constraints and Opportunities**
Institutional measures (continued)	Kern County Water Agency and local water districts should form a drainage management entity responsible for coordination and joint management of subarea-wide drainage problems. Not accomplished.	This objective could be promoted.
	Both the Federal and State governments should explore ways of providing a portion of the financing needed to implement irrigator source-control actions and to invigorate existing programs. SWRCB and DWR are the only agencies that have loans for source control action. Considerable loans have been provided for irrigation system improvements. USBR and DWR have provided funding for source control demonstration projects.	The California State Department of Water Resources, the Department of Food and Agriculture, and the State Water Resources Control Board, could provide loans and grants for source-control actions, if funds were made available.
	The U.S. Department of the Interior and the State of California should jointly develop a technical assistance program to ameliorate the drainage problem. The DOI and State agencies have various programs to provide technical assistance to districts.	More coordination and cooperation among agencies could help to accomplish this goal.
	The State of California should expand and intensify its program of on-farm water conservation. DWR has an on-farm water conservation and drainage reduction program. Limited funding has curtailed projects	More funding to DWR Office of Water Use Efficiency could be made to accomplish this goal.
	Within the State and federal projects areas, the State and federal government should lead in planning for the regional drainage-water treatment and disposal needs.	No planning work has been initiated for the State. Within the Federal water service area, the Department of the Interior is planning for regional drainage-water treatment and disposal needs through the court ordered drainage re-evaluation processes. CALFED Water Use Efficiency and Drinking Water Quality programs could provide the means for accomplishing this goal.

Agricultural Drainage in the San Joaquin Valley A Gap Analysis

Appendix A

The San Joaquin Valley Drainage Implementation Program October 8, 2002

This appendix consists separate gap analysis reports for each of the following drainage management measures recommended by the 2000 AHCC Report: Source Control, Drainage Reuse, Drainage Monitoring, Evaporation Ponds, Drainage Treatment, River Discharge, Salt and Selenium Utilization, Land Retirement, and Groundwater Management. Each report contains specific recommended actions. For each action, projects undertaken and planned since 2000; and constraints and opportunities to move forward are presented.

Source Control

To facilitate in-valley options a reduction in drainage water volume at the source will result in more cost-effective treatment or disposal. Reducing the amount of subsurface drainage water through source reduction continues to be an essential component in dealing with the subsurface drainage. The potential exists to substantially reduce subsurface drainage by shortening ½-mile long furrow lengths by one-half and then applying proper management to the modified systems. Converting to drip irrigation, linear-move machines, etc. also has the potential to greatly reduce subsurface drainage. Water table management has potential for drainage reduction by adjusting irrigation schedules to encourage crop use of shallow groundwater or by manipulating water table levels through the design and management of drainage systems. An important component of any system improvement is proper irrigation scheduling to prevent over irrigation.

Salinity is a limiting factor on the amount of source reduction attainable. Some minimum amount of leaching must occur to prevent adverse levels of soil salinity from accumulating in the root zone. Therefore, an ultimate sink for salts is still needed if source reduction is to be a sustainable action.

Improved irrigation practices can reduce the deep percolation while providing required leaching to maintain salt balance the crops water needs for evapotranspiration. Irrigation distribution uniformity is a measure of the 'evenness' of water application to a field when water is applied unevenly more water is required to prevent deficit irrigation and reduction in crop yields. To improve distribution uniformity a number of practices have been developed and implemented for surface irrigation. Improvements have included shortening furrow lengths coupled with shortened set times, installing gated pipe and surge valves, alternate furrow irrigation, furrow compaction and on demand water deliveries. All of these practices have been shown to reduce deep percolation by increasing distribution uniformity in the field.

Historically irrigated agriculture in California has depended on surface irrigation. Recently it has been shown that new irrigation methods can decrease deep percolation while maintaining and sometimes even increasing yield. Irrigation methods that have been shown to reduce deep percolation includes the use of drip and micro-irrigation, solid set and movable sprinklers, linear move and center pivot systems. Distribution uniformity for these systems are generally much higher than for surface systems and installation represents a significant potential to reduce deep percolation. In all cases the irrigation management and system selection is dependent on field specific criteria including soil type, water source and quality, and crop grown. In addition ongoing educational programs such as the Irrigation Technology Research Center are helpful in alerting water users to the potential for changes in management and system upgrades to improve distribution uniformity.

The first steps to improving irrigation scheduling have occurred with DWR's California Irrigation Management Information System (CIMIS) program. A network of weather stations and staff have been put in place to provide evapotranspiration information that can be used to help growers and irrigators meet the exact water needs of crops and reduce surplus irrigation that leads to deep percolation. The usefulness of CIMIS as an irrigation tool to reduce deep percolation has been demonstrated, however, widespread use of CIMIS has not been realized due to lack of awareness and delivery systems that prevent on-demand water deliveries.

The use of shallow ground water to supplement or meet crop demands has shown promise in reducing drainage volumes. Presently the state of knowledge provides encouraging data but full-scale demonstration projects are needed. Projects need to show the effectiveness of the system and determine the actual contribution of ground water to crop needs. Irrigation scheduling depends on determining how much water is needed to replace the water used by a crop. If water can be supplied by ground water then the amount of water needed for each irrigation event is reduced and only the irrigation water needed to fill the soil moisture deficit and leach salts from the root zone should be applied.

Source control, by itself, does not offer a sustainable solution to the drainage problems in the San Joaquin Valley. However, source control does provide a method to reduce the volume of drainage water that must be disposed of. Source control must therefore be seen not as a solution to the drainage problem but an important step toward an ultimate solution.

Source Control actions developed by SJVDIP in 2000	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Techniques for the most efficient direct crop use of shallow groundwater, without increased soil salinization, need to be developed and implemented.	**DWR/BVWD/USDA** Prop 204-2001 Crop Production with In-situ Use of Shallow Saline Groundwater, Reuse of Drainage Water, and Active Drainage System Management. **UC** Response of crop yield and water table to subsurface drip irrigation of processing tomato under saline, shallow groundwater conditions.	DWR/USDA shallow groundwater management	Need further technical development.	Growers desire to reduce drainage volume and avoid discharge costs.
*Continue irrigation and drainage workshops and other educational opportunities.	**DWR/Cal Poly** 2001 Irrigation System Evaluation Short Course. **DWR/USBR/Pond Shafter Wasco RCD** 2001-02 Expanded Mobile Lab Irrigation System Evaluations. **DWR/CSU Fresno** 1997-2002 Education. Workshops for On-Farm Irr Manage for Source Reduc. of Deep Perc. and Drain. **DWR/P-S-W RCD** 2001 Irr Manag. Educ. and Training Workshops through the Use of Demonstration Farms. **USBR/Cal Poly** Field evaluations and rapid appraisals on operation and management techniques – Central Valley Water Districts.	Ongoing	Funding	DWR Office of Water Use Efficiency has a mobile lab program to help growers improve irrigation. USBR also has irrigation management program.

Source Control actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Continue and expand implementation of the water conservation program.	**DWR OWUE** Mobile Lab Program. **DWR OWUE** CIMIS and Ag. Water Management Plans. **USBR/CVP Districts** grants for water conservation program updates and software improvements.	**DWR OWUE** Agricultural Water Conservation Program	Lack of funding. Lack of incentives for water conservation. Fear of growers loosing water.	Ag Water Management Planning process, tiered water pricing, encouraging transfer of conserved water.
Develop pressure chamber methods to facilitate implementation of shallow groundwater management in coordination with surface irrigation.	Technology has been developed.	No further development is needed.	Skilled worker, may not be applicable to all crops,	Technology exists. Farm advisors and cooperative extension should promote
*Develop updated water management plans for efficient use of water.	Ag. Water Management Plans. CVPIA water management plans. **NRCS** Environmental quality incentives program. **USBR/CVP Districts** annual updates and 5-year plan revisions.	District Water Management Plans	BMP implementation costs districts.	NRCS Environmental Quality Incentives Program may provide funding. Agencies and AWM Council can provide technical and financial assistance
*Develop and demonstrate economic incentives through combined technical, environmental, and economic systems approach where economic benefits exceed costs.	**CALFED Water Use Efficiency** and Ecosystem Restoration Program incentive programs and OWUE loans and grants and technical assistance for water conservation.	**CALFED WUE and ERP** incentive programs	Limited source of funding. Historical low demand for loans	CALFED technical and financial assistance programs

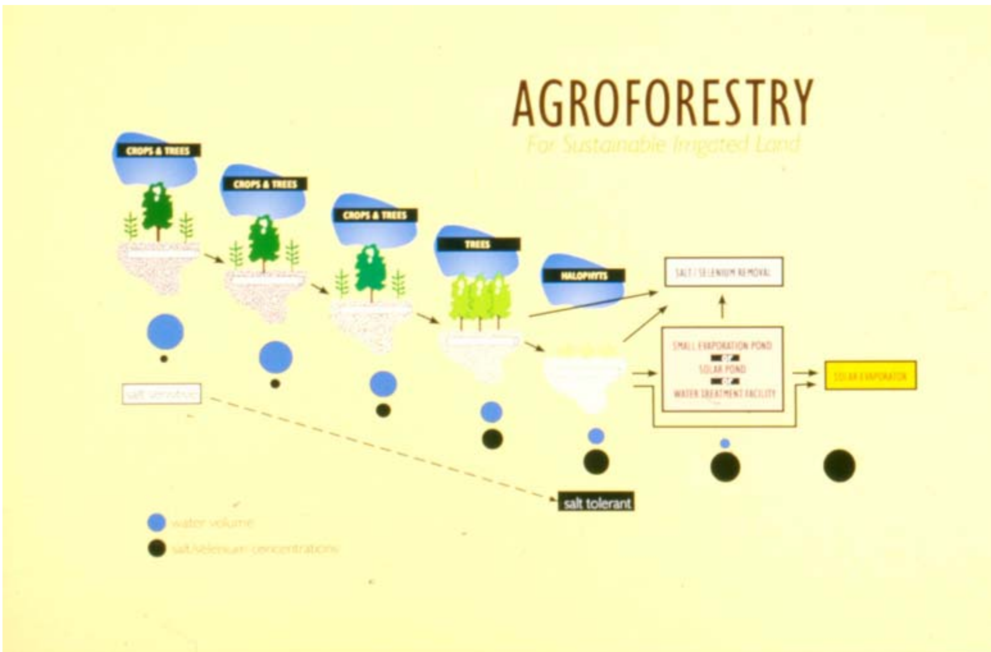
Source Control actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Improve irrigation scheduling and management, where applicable.	**DWR** Prop 204-2000 and 2001 Survey of Location and Acreage of Westside SJV Irrigation Methods. **DWR** Prop 204-2000 Improved Irrigation Management Planning. **DWR**. **NRCS** Environmental Quality Incentives Program. **UC** Validation of protocols for using trunk diameter and tree water potential measurements in orchard irrigation scheduling. **USBR/Cal Poly** water irrigation seminars on management and application. Portable flow measurement. **USBR/CVP Districts** variable frequency drive upgrades. **USBR/WWD** crop rotations and varieties in cotton. **USBR/CCID** Canal lining. **USBR/SLDMWA** flow meters.	**DWR OWUE** technical and financial assistance programs	Education and awareness	Outreach Encourage local entities to implement education and outreach programs focused on locally feasible BMPs to reduce source loads, increase water use efficiency. Financial assistance may be available from Prop 13 SWRCB/CALFED Non-point Source Pollution Prevention RFP's.
*Continue existing water transfers program for improved management of water supplies.	**CALFED** water transfer program	**CALFED**	Uncertainty in ownership of conserved water	Desire and demand for transfer of conserved water
*Establish moderate fees for drainage discharge not to exceed the threshold for economic farming viability.	Grasslands bypass project selenium load limit fees as a part of SL Drain Use Agreement. Drainage assessment from drained lands in the Tulare Drainage District.	None	Resistance form growers for such assessments	Discharge fees can be used for drainage management and support of drainage-related work for the assessed lands.

Source Control actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Continue use of crop-rotation cycle to optimize crop use of shallow groundwater.	Practiced in Tulare Basin and in Westlands Water District	None	Requires deep-rooted crops, which may not be applicable in all areas. Requires outreach.	Can be very effective for lowering the water table and reducing volume of drainage water and discharge fees.
*Expand conversion of furrow irrigation to hand-move sprinklers, where applicable.	Grassland Area Farmers use this practice to reduce drainage volume in early part of irrigation season. SWRCB low-interest Revolving Fund loan has been used by Grassland area districts for irrigation systems.	There is a trend for the conversion	Requires capital investment, may not apply to all crops. Requires more flexible water delivery system.	Increased yield, water conservation, avoiding drainage fees. There may be opportunities in Tulare Lake Basin. SWRCB low-interest Revolving Fund loan program can be used.
*Promote reduction in pre- and early crop irrigation depth of application through use of sprinklers and other methods, where applicable to soil types.	Grassland Area Farmers, Westlands water District. SWRCB low-interest Revolving Fund loan has been used by Grassland area districts for irrigation systems.	None	Requires capital investment, may not apply to all crops. Requires more flexible water delivery system.	Increased yield, water conservation, avoiding drainage fees. There may be opportunities in Tulare Lake Basin. SWRCB low-interest Revolving Fund loan program can be used.
*Implement improved furrow irrigation techniques including skip-rows and shorter rows for appropriate soil conditions.	Grassland Area, Tulare Lake Basin	None	Shorter rows takes land out of production and undesirable for large mechanized farms	Improves water management
*Promote use of gated pipe and surge valves where appropriate.	Grassland Area, Westlands Water District	None	Good for furrow	Loans and grants and technical assistance

Source Control actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Continue to develop and promote efficient methods of irrigation.	**DWR/Cal Poly** 2001 Salinity Buildup on the Periphery of the Wetted Area in Subsurface Drip Irrigation. GAF and WWD programs	DWR and USBR, and NRCS water conservation programs	Lack of funding.	Desire exists.
*Promote conversion to higher value crops to make improved irrigation systems more cost-effective, if possible.	None planned. But these actions are taken place driven by low commodities prices and reduced water supplies farmers are switching to higher value crops and efficient irrigation systems	None planned	Farmers decision	Incentives programs
*Provide continuously available irrigation water supply (flexible delivery) to enable conversion to micro-irrigation systems.	Practiced in WWD, Panoche Water District and other districts. SCADA systems	None	Requires investment. Energy costs will increase.	Saves water, reduces weed control costs and management costs.

Drainage Reuse

Reuse of saline drainage water is one management option on the West Side of the San Joaquin Valley for reducing the volume of drainage water. The drainage water is reapplied to a succession of more salt tolerant crops until the resulting drainage water is too saline for crop growth. The saline water is then disposed of by allowing the water to evaporate leaving the salts behind. These salts must then be managed or disposed of according to state regulations.



Management practices that result in less drainage water are attractive since they would reduce the area required for environmentally sensitive evaporation ponds and reduce the costs associated with disposal of the final effluent.

The salinity and sodicity of drainage water are the main parameters that determine the feasibility of reuse. In addition, the presence of trace elements (e.g., B, Se, and Mo) in the drainage water pose a potential threat to crop yields, crop quality, aquatic life, the consumer and environmental quality. A successful adoption of reuse will require an integrated approach requiring new and flexible on-farm skills related to irrigation, crop and soil management within the context of being economically feasible and environmentally sound.

Drainage water may be used for irrigation for two purposes: to reduce the volume of drainage water and to achieve an economic return from a crop. The goal is to utilize drainage water to increase agricultural profitability while at the same time to reduce the volume of drainage water that must be disposed of by other means. Use of saline drainage water requires several changes from standard management practices such as selection of appropriate crops, improvements in water and soil management, adjustments in crop rotations and in some cases, the adoption of advanced irrigation technology.

Sequential reuse is the practice of using part of the farm, usually the problematic areas or an area where the saline water table is close to the soil surface, as the reuse area. It consists of a sequence of fields, within the boundaries of the farm, that are systematically irrigated with drainage water of increasingly higher concentrations for the main purpose of managing the salt on the farm and reducing the volume of drainage water. Integrated on Farm Drainage Management (IFDM) is the use of drainage water on successively more salt tolerant crops. Presently the main uncertainties with IFDM are management of soil and the lack of a defined end point for the salts that are concentrated through reuse.

Two other methods have been proposed and field-tested for recycling saline drainage water. The blending strategy involves mixing saline water and good quality water together to achieve irrigation water of acceptable quality for the chosen crop's salt tolerance. This water is then used for irrigation. The cyclic strategy is where saline drainage water is used solely for certain crops and only during certain portions of their growing season. The objective of the cyclic strategy is to minimize soil salinity (i.e. salt stress) during salt-sensitive growth stages or when salt-sensitive crops are grown.

With a cyclic strategy, the soil salinity profile is not in steady state but is allowed to vary, permitting crops with lesser tolerances to be included in the rotation. Using equivalent amounts of drainage water, the cyclic strategy keeps the average soil salinity lower than that under the blending method, especially in the upper portion of the profile that is critical for emergence and plant establishment. The different reuse methods are not mutually exclusive and in fact a combination of one or more methods may be most practical.

The long-term success of reuse will depend on the evolution of practical management strategies including careful management of irrigation water, controlled drainage flows to foster crop use of saline/sodic groundwater and the availability of an ultimate sink for salts concentrated in the final drainage water. Drainage reuse is not sustainable unless a final treatment and disposal option can be implemented. As with source reduction reuse can't be viewed as a solution to the drainage problem by itself but must be seen as a tool that can be used to reduce the volume of drainage water that will ultimately need treatment and/or disposal. Other questions that must be addressed with drainage reuse include crop selection, kinetics of salt equilibrium in the soil and shallow ground water and potential problems in compliance with regulations such as the toxic pits act as it relates to the final end point in IFDM. Senate Bill 1372 has been proposed to allow design and operation of solar evaporators to avoid the environmental impacts.

A solar pond, may be considered as reuse, is constructed by placing very concentrated saline water on the bottom of a basin, with less saline water at the surface. A density gradient is created with the densest water at the bottom and the least dense water at the top of the water column. This arrangement provides an opportunity to capture solar energy and convert it into electricity. Solar rays pass through the stratified, ponded water, heating and raising the temperature of the lower saline water. In ordinary ponds, warmer and lighter bottom water rises to the surface, displacing heavier, colder water above and causing convection currents. These currents rapidly disperse the heat throughout the pond, preventing any portion of it from reaching a high temperature. The dense saline water at the bottom of a solar pond can stabilize under solar heating, with cessation of convection currents and pond circulation. The bottom layer of hot brine, called the storage zone, is the system's energy accumulating component. The stored heat must then be extracted from the lower layer of the pond for utilization. Potentially, solar ponds allow the opportunity to produce energy as well as dispose of brine.

Drainage Reuse actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Provide educational programs on drainage reuse	**DWR/CSUFCIT** 1999 Integrated On-Farm Drainage Management Workshops. **DWR/WRCD Prop 204-2001** Expanded Demonstration Projects for Integrated On-Farm Drainage Management.	**SWRCB/CVRWQCB/Westside RCD** IFDM Education and Training Workshops	None	Demonstration projects, publications, workshops.
*Continue development of drainage reuse for production of forage, pistachios, and other salt-tolerant crops.	**DWR/UCR** Prop 204-2000 IFDM Present Status and Further Research. **DWR/Lost Hills WD** 1998 Lost Hills Drainwater Reuse Project. **DWR/UC Davis** Prop 204-2000, 2001 Using Forages to Manage Drainage Water in the SJV. **UC** Evaluation of salt-tolerant forages for sequential reuse systems. **UC** Using forage and livestock to manage drainage water in the San Joaquin Valley. **USBR/CSUF** Soil salinity assessment and determination of soil hydraulic parameters at Red Rock Ranch.	**DWR/CSU Fresno** 2003 Suitability Assessment of Salt Tolerant Forages and a Halophyte for Sequential Drainage Water Reuse Systems: Plant Water Use, Forage Quality, and Productivity.	Long-term viability, financial	This approach is being considered in Grasslands area where drainage discharge is limited. Financial incentives will encourage implementation.

Drainage Reuse actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Evaluate feasibility of Integrated On-Farm Drainage Systems including salt grass, halophytes, and solar evaporators areas.	**DWR/SJD** Prop 204-2000, 2001 Development of Wildlife Management Criteria for the Operations of Integrated on Farm Drainage Management Projects. **DWR/SJD** Prop 204-2000, 2001 Monitoring Wildlife Impacts at IFDM Demonstration Projects (Red Rock Ranch). **DWR** Prop 204-2000, 2001 Planning and Design for Grasslands Drainage Reuse. **DWR** Prop 204-2001 Expanded Demonstration Projects for Integrated On-Farm Drainage Management. **USBR** support for drainage reuse at Red Rock Ranch.	Proposition 204 funded projects salt tolerant crop selection, study of biomass, San Joquin River Management Improvement Program, Red Rock Ranch redesign.	Management of solar evaporator, potential violation of Toxic Pits Act, and wildlife impacts where selenium is high. Use or disposal options of salts are still uncertain.	A State senate bill is currently considering some form of waiver for solar evaporators (not approved yet). There is desire in the farming community to manage drainage on-farm. The IFDM is currently under development and redesign.
*Develop customized and flexible regional and site-specific reuse system designs, marketable halophytic crops, and trees.	**DWR/Lost Hills WD** 1998 Lost Hills Drainwater Reuse Project. **DWR/UC Davis** Prop 204-2000, 2001 Using Forages to Manage Drainage Water in the SJV.	**DWR/USDA-ARS** 2003 Developing biofuel and selenium-enriched forage from canola irrigated with selenium-laden drainage waters on the west side of central California	Two farm-level reuse systems have undergone many modifications and fully developed system has yet to be designed.	There is desire for reuse systems.

Drainage Reuse actions developed by SJVDIP in 2000	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Improve halophytic crop selection.	**UC** Evaluation of Atriplex as a potential new crop for integrated production systems in the San Joaquin Valley.	DWR Drainage Program	None	Universities should promote research on crop selection and disseminate the information.
*Determine optimal blending/cyclic reuse strategies.	**DWR/Lost Hills WD** 1998 Lost Hills Drainwater Reuse Project. **USBR/Firebaugh Canal WD** Improvement to database on re-use, billing, and deliveries.	None	Lack of knowledge, long-term salinity problems, and financial support.	It is implemented in Panoche Drainage District at a large scale. Financial assistance can increase usage.
*Improve trace element management.	**DWR** Prop 204-2000 IFDM Toxic Trace Element Reduction Project Planning. **SWRCB/UCB** 2000 (General Fund) Environmental Acceptability the IFDM System: Assessment of Potential Movements of Selenium Through the Food Chain	None	Lack of funding.	Selenium volatilization and selenium utilization research can improve selenium management.
*Improve drainage reuse economics.	**DWR/UC Davis** Prop 204-2000 Using Forages to Manage Drainage Water in the SJV. **UC** The economics of integrated drain water management in the Central Valley.	**DWR/UCR** 2003 An Economic Analysis of Solar Evaporators and Evaporation Ponds	Saline water can only be used for low value crops.	Crop selection can improve the economics of drainage water reuse.
*Continue to encourage achievement of a low leaching factor.	The concept is known	None	May increase soil salinity.	Can be used for salt tolerant crops and in early irrigation season.

Drainage Reuse actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Improve long-term salinity management through crop rotation, irrigation management, adequate leaching, and on-farm or district drainage.	**DWR/UC Davis** Prop 204-2000 Using Forages to Manage Drainage Water in the SJV. **DWR/BVWD/USDA** Prop 204-2001 Crop Production with In-situ Use of Shallow Saline Groundwater, Reuse of Drainage Water, and Active Drainage System Management. **PWD Prop 204** Impacts of drainage re-use on water district salinity budgets: a case study of two west-side irrigation water districts.	Ongoing projects.	Technical, institutional, and environmental issues of salt disposal part of the system.	There is desire to reuse drainage water and technology is available. Disposal or use of the final brine at the farm or district level is technically possible, if potential environmental damages can be controlled or mitigated.
*Improve sodium management through expanded use of gypsum combined with re-tillage.	A normal practice advocated by cooperative extension.	None	None	Outreach
*Further develop solar pond technology operating guidelines, estimate potential energy production, and evaluate economic factors through a pilot project.	**DWR/USBR** Further Development of Solar Pond Technology Operating Guidelines, Estimate Potential Energy Production, and Evaluate Economic Factors Pilot Project.	**USBR/DWR** intend to study solar pond technology. **DWR 2003**. Application and Feasibility of Salinity Gradient Solar Pond Technology: Second Phase	Selenium removal is needed. Limited disposal capacity, costs. Ecosystems risks	Energy production, technology is available, there is interest in some locations in the Valley. A project has been funded by DWR to develop a proposal for possible joint funding by CALFED/United States Bureau of Reclamation/Department of Water Resources/SJVDIP of a Solar Gradient Pond and Treatment Facility Feasibility Study

Drainage Reuse actions developed by SJVDIP in 2000	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Encourage research and field documentation of boron effects and salinity/boron interactions on crop yields.	Work has been done	None	None	Support of research projects at the university.
*Monitor forage irrigated with reused drainage for possible molybdenum impacts on young cows.	Work has been done	None	None	Can be made a requirement for the agency-funded projects.
*Investigate selenium exclusion from the solar evaporator food chain.	**SWRCB/UCD** 2000 (General Fund) Reducing Selenium Loads and Ecotoxic Risk in IFDM Systems Using Solar Evaporator Basins that Combine Invertebrate Harvest with Alagal Volatilization of Selenium.	Ongoing	None	Support of research
*Evaluate the environmental impacts of solar evaporators.	DWR/USFWS study to develop BMP's for solar evaporators	Ongoing work	None	Cooperation among DWR, USFWS, and DFG can help develop BMPs. Work started.

Monitoring

Monitoring is a key component to each of the drainage management actions. Currently rigorous monitoring of surface waters receiving drainage water is occurring. Most of this monitoring is driven by discharge permit requirements issued by the Regional Water Quality Control Board. The Grasslands Bypass project is monitored for selenium discharge into the San Joaquin River and penalties are levied against the dischargers if drainage water exceeds the maximum allowable limit for selenium. Dischargers to surface evaporation basins are also required to monitor drainage water for selenium. Surface water monitoring is required to protect fish and wildlife and their habitats. In addition temporal response of surface water to management practices are rapid and changes can be seen on time scales as small as weekly.

Monitoring of soil and ground water has received less attention due to funding limitations and temporal changes occurring over time periods of years and even decades. Evaluation of management actions on the long-term sustainability will require salinity, selenium and boron monitoring to determine salt balance in the drainage impaired areas of the Valley. Presently there are questions as to where or if salinity is accumulating in the Valley.

In the future surface water monitoring will continue or increase from present levels due to regulatory requirements, however, without sustained monitoring of soil and ground water proposed benefits of management actions will not be quantifiable.

Continuous funding of existing baseline monitoring and performance monitoring should be provided. Additionally, performance measure monitoring of new projects, particularly agency funded projects should be required in any project solicitation packet.

.

Drainage Monitoring- actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
To properly implement management of drainage and drainage-related problems, both the problems and the progress in solving them must be monitored. This is especially important because of the changing nature of the drainage problem and the flexible array of measures required for management. Monitoring all aspects of the problem and the effects of management will be critical to using the plan as a flexible guide to remedial actions.	**USBR** Monitoring of the Grasslands Bypass Project and the San Joaquin River. **USBR** Continued monitoring at Kesterson. **Grassland Area Farmers, CVRWQCB** monitoring of the Grasslands Bypass Project. Pond operators monitoring programs required under Waste Discharge Requirements. **UC** Transformation of selenium in Tulare Lake evaporation ponds (measurement of selenium speciation in the TLDD sediments). **UC** An investigation into the ecotoxicology of selenium bioaccumulation in birds. **UC** Chemical nature of selenium in agricultural drainage sediments and its implications for bioavailability.	Existing programs will continue. Monitoring at Red Rock Ranch will also continue. DWR real-time monitoring project.	Lack of a coordinated and funded monitoring program. Monitoring has not been part of the requirements of funded projects.	Coordinate agency-funded monitoring programs for technical and financial gain and efficiency. Incorporate monitoring and reporting requirements in all agency-funded projects.

Evaporation Ponds

One means of disposing of drainage water is to set aside a portion of land to create a basin for ponding water for evaporation. Except for the limited opportunity to discharge drainage into the San Joaquin River, evaporation ponds in the Tulare Subarea and two experimental solar evaporators elsewhere are the only current means of isolating salt from productive agricultural lands. Evaporation ponds play a major role in sustaining agriculture on drainage-impacted lands in Tulare Lake Basin. Only 10 ponds with a surface area of about 4,900 acres are presently active and managed by seven operators.

Waterfowl and shorebirds seasonally inhabiting or utilizing evaporation basins for resting, foraging and nesting may be adversely impacted from exposure and bioaccumulation of selenium in the food chain. From 1989 to the present, adverse selenium impacts to American avocet and black-necked stilts have been studied extensively in the environs of Tulare Lake Basin. For those ponds with waterfowl impacts, modifications in the design and management of evaporation ponds have been implemented, and compensation and alternative habitats have been developed as site-specific mitigation measures. The results of biological monitoring of mitigation measures conducted since 1993 show considerable promise of protecting waterfowl. Substantial reduction in the numbers of waterfowl (particularly American avocet and black-necked stilts) nesting at evaporation basins has occurred after modifications were implemented. In addition, the number of stilts and avocets nesting at compensation habitats is higher than originally expected.

Evaporation pond option can be severely affected by the presence of selenium, which can impact wildlife using the evaporation ponds. Waterborne and sediment selenium within evaporation ponds bio-accumulate into the aquatic food chain by bio-concentration and bio-magnification mechanisms. The extent of bioaccumulation depends on the route of exposure (e.g., diet, water, or sediment) and chemical form of selenium. Some previously operational evaporation ponds have shut down, and are subject to closure and post-closure maintenance, because of regulatory criteria and costs associated with mitigation measures.

The future utilization of evaporation ponds for drainage water disposal is dependent on practices to eliminate or minimize bird impacts. In the Tulare Lake Basin, a variety of waterfowl and shorebirds seasonally inhabit or utilize evaporation ponds for resting, foraging, and nesting. Adverse impacts may range from impaired health and condition of adult birds, reduced hatchability of eggs, and embryonic deformities. Although species–specific differences exist among waterfowl, the focus has been mainly on American avocet and black-necked stilt. A number of complex interacting environmental and biological factors need to be taken into account to assess the potential adverse effects of selenium to wildlife.

The selenium concentrations in subsurface drains discharged to evaporation ponds vary widely, ranging from less than 2 to more than 200 ppb. Research has been conducted on selenium speciation in waters and sediments and selenium uptake by plants such as widgeongrass, macroinvertebrates such as brine fly, and vertebrates such as Mosquitofish. The pathways and fate of selenium in the aquatic food chain and toxicity to higher trophic forms are complex. There is a need to consider not only water borne selenium but also sediment selenium in assessing potential hazards to wildlife. It is currently thought by some that protein selenium in the food chain is more toxic than other forms of selenium.

Presently available scientific-based risk analyses indicate that such analyses require site- and species-specific appraisals, including spatial and temporal variabilities. Although selenium is the principal constituent of concern, others such as salts and boron are of concern, too. A number of other uncertainties exist in evaluating potential biological risks of selenium in ponds including, but not limited, to post-hatch juvenile mortality, the form of selenium in the pond system, sub-lethal exposure effects, and short-term exposure on migratory birds.

The results of site-specific environmental analyses showed that some evaporation basins are characterized by low waterborne selenium concentrations and the risk of potential adverse effects on waterbirds is minimal so that compensation for unavoidable losses are not necessary. At other basin facilities, such as those operated by Tulare Lake Drainage District, Westlake Farms, Britz, Lost Hills Water District and Rainbow Ranch (pond closed and converted to IFDM system), modifications to evaporation basins and/or compensation for unavoidable losses has been identified. A number of protocols have been proposed to estimate unavoidable adverse impacts on American avocet and black-necked stilts, and the acreage of uncontaminated compensation wetland to mitigate these unavoidable losses.

Moreover, a second protocol has been proposed for the creation of alternative wetland habitats to provide foraging habitats for targeted waterbirds so that selenium dosing from contaminated basins could be reduced. Based upon preliminary estimates of unavoidable losses and required compensation and/or alternative habitats, Waste Discharge Requirements were adopted for evaporation basins.

Redesign and maintenance of evaporation ponds to reduce impacts to wildlife may include a minimum water depth of 2 feet, steepening levee slopes, reducing vegetative cover, removal of windbreaks, disease surveillance and control programs, invertebrate sampling, and bird hazing. All of these measures contribute to decreased use of evaporation ponds by birds. Methods that cause disruption of the selenium food chain, such as the commercial production and harvesting brine shrimp within evaporation ponds, are presently being developed and implemented. Reduction in selenium concentration in drainage water before discharge into ponds, through biological treatment methods such as flow-through wetlands, can reduce the hazard to birds. However, none of these practices provides an absolutely safe bird habitat without some potential impact.

The results of biological monitoring at mitigation wetland habitats conducted to date have been promising. Monitoring is continuing to refine the performance of compensation habitats and to address questions concerning issues such as the use of saline water supplies having low-selenium concentrations as a water supply to wetlands, performance under drought conditions, alternative wetland design and operations, and the relationship between waterbird production on compensation wetlands relative to the mitigation requirements to reduce unavoidable evaporation basin impacts to less-than-significant levels, the function of alternative habitats for reducing selenium dietary loads, and the contribution of compensation habitat production to the adult waterbird population and the associated assessment of net environmental benefits.

Evaporation Pond- actions developed by SJVDIP. Evaporation ponds are the only means of drainage disposal in the Tulare Lake basin and may be economically feasible for other areas where selenium concentration is low.	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Continue establishment and operation of evaporation ponds in compliance with WDR's, including monitoring and compensation habitat, where applicable.	Other than existing evaporation ponds in Tulare Lake Basin no new evaporation ponds have been establsihed.	None	Wildlife impacts are likely and mitigation of pond operation is costly when selenium concentration is high.	Feasible when selenium levels are low.
*Research and demonstration projects on alternative and compensation habitats required to mitigate the evaporation pond impacts need to continue.	Data collection at Tulare Lake Drainage District compensation habitat and other ponds.	None	Mitigation of pond impacts is costly.	Long-term research data should be analyzed to avoid impacts and reduce mitigation costs.
*Investigate effectiveness of mitigation measures, the benefits of alternative habitat using low-selenium saline water, and other scientific investigations.	**DWR/TLDD** monitoring at its Compensation Habitat. **DWR/TLDD Prop 204-2002** Feasibility determination and design of a wintering waterfowl wetland habitat using a low-selenium saline agricultural drainage water supply.	None	Potential for accumulation of selenium and potential wildlife impacts	Drainage water use for mitigation habitat will reduce costs.
*Investigate selenium partitioning and isolation as a result of pond stratification.	**DWR** Rainbow Ranch Stratification Study. (Other studies by Michael Frye at UC Davis Salinity Lab). **UC Prop 204 2002** Selenium mass balance and modeling in agricultural evaporation basins.	None	Doesn't remove selenium from the system.	If proven, it will reduce wildlife impacts and have low cost.

Evaporation Pond- actions developed by SJVDIP. Evaporation ponds are the only means of drainage disposal in the Tulare Lake basin and may be economically feasible for other areas where selenium concentration is low.	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Continue development and expansion of aquaculture production in drainage water and commercial harvest of brine shrimp from evaporation ponds.	**TLDD** shrimp harvest program.	None	Optimum growing conditions appear to be limiting factor for increased production.	Demand exceeds available supplies. May reduce selenium in the ponds.
*Implement measures to further reduce drainage volume discharged to evaporation ponds in LHWD.	**DWR/Lost Hills WD** 1998 Lost Hills Drain water Reuse Project.	None	May result in increase selenium concentration in drainage water	Promote on-farm management and reuse.
*Conduct research to establish site-specific objectives and parameters and regulatory criteria for evaporative ponds.	USFWS protocols for mitigation habitats	None	Requires long-term studies and monitoring	Agency and districts cooperative studies to develop guidelines and objectives
*Investigate and pursue evaporation pond technology	None	**USBR** intends to study enhanced evaporation ponds.	Technical and economic feasibility. Will require energy	Warm Valley climate is appropriate for enhanced evaporation.

Drainage Treatment

Processes designed to remove potentially harmful constituents such as selenium and salinity would increase the potential beneficial uses of drainage water. Presently there are three treatment options that have received attention and show promise.

(1) At present, reverse osmosis (RO) is the most promising technology for complete treatment of drainage water, i.e., removal of dissolved salts and selenium. Advances in membrane technology have increased the efficacy of RO treatment. The technology is available; implementation of RO treatments driven by economic considerations. The capital costs for constructing a RO treatment facility are estimated to be between $2-$3/gal/day of capacity. The higher investment would be required if extensive pretreatment of the water prior to RO were necessary. The operating costs are estimated to be between $150-$300/acre foot. RO is an energy intensive operation and the costs are greatly affected by energy costs. The stated capital and operating costs do not include the costs of collecting the drainage, delivering the treated water, or disposing of the waste brine.

A number of benefits could be associated with implementation of membrane treatment technologies such as RO treatment systems alone or in combination with other drainage management options. RO results in one useful product now in short supply in the San Joaquin Valley – pure water. The purified water could be sold to a municipality, possibly at a profit to the RO operator. The resultant brine could be used on halophytic crops. The concentrated drainage could then be discharged into a solar evaporator resulting in salt desiccation and recovery. Although a commercial market for the salt is not available at the present time, if RO coupled with salt separation and disposal or utilization could be accomplished economically, the cycle would be closed and drainage would have a beneficial use. In the absence of a market for salt products, the brine or salts have to be discharged into lined disposal facilities.

The two major obstacles to extensive RO technology implementation are the costs of operation and the current limitations on brine disposal. Purified water would have to be sold at a price greater than most agricultural operations could afford to offset the operational costs. Urban water users could come closer to affording the price for the purified water. Therefore, treatment of drainage water through RO becomes more feasible if water transfer through an open market is developed between the agricultural and the urban communities. Growers could use treated drainage water in lieu of surface water supplies, which could then be transferred to the urban sector.

(2) Treatment of drainage water to remove only selenium would still leave very saline water requiring reuse or disposal. Nevertheless, the removal of selenium would increase the options for reusing or disposing of the drainage water without biological impact.

Several laboratory investigations have demonstrated that bacteria can effectively reduce selenium. However, bacterial reduction has not been adequately demonstrated on a field scale operational level. Large reactors are currently or soon will be field-tested in the Panoche Drainage District and the Broadview Irrigation District.

The selenium concentration in water can be reduced in open systems. For example, an algal-bacterial selenium removal system consisting of a series of specially designed ponds has been tested. The concept of this process is to grow micro-algae to use nitrate, and then utilize the naturally settled algal biomass as a carbon source for native bacteria. The bacteria in the absence of oxygen reduce the remaining nitrate to nitrogen gas, and reduce selenate to insoluble selenium. The insoluble selenium is then removed from the water by sedimentation in deep ponds and as needed, by dissolved air floatation and sand filtration. This process in undergoing continued evaluation.

(3) Flowing water through wetlands or carbon substrates has been demonstrated to reduce selenium concentrations in water. Removal of selenium occurs by several mechanisms, including reduction of inorganic

selenium to elemental selenium, adsorption of selenite to the charged surfaces of minerals and organic matter, plant uptake, and microbial volatilization, plus some inadvertent seepage losses. Presently research is trying to identify and quantify the fate of the selenium. The selenium removed by water may be volatilized, accumulated in the sediment, or incorporated in the plant tissue. Flow through systems are anticipated to reduce the selenium concentration in the water, but not to completely remove it. A positive feature of the wetland flow through system is that it may provide a relatively inexpensive means to reduce the selenium load in drainage water. However, inorganic selenium may be converted to a more toxic form of organic selenium. The extent of selenium removal by a flow-through wetland system varies with hydraulic residence time and with seasonal changes in temperature.

One drawback of an open system for selenium removal is the potential for bird exposure. Thus, the treatment process is not 100% ecologically safe. Netting or waterfowl hazing may be necessary to prevent wildlife use of the wetlands. One major consideration is the trade-off between potential increased waterfowl impact from the treatment process, contrasted with the potential reduced waterfowl impact associated with using the drainage waters after treatment to reduce selenium. Reduction of selenium from the drainage water prior to discharge into an evaporation pond through use of the flow-through wetland treatment process, may contribute to an overall reduction in wildlife hazard relative to the hazard associated with pond discharge without the treatment process.

Drainage Treatment actions developed by SJVDIP in 2000. Treatment is the key to solution of environmental problems associated with agricultural drainage. Development needs to continue on all feasible and promising means of drainage treatment.	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Determine primary purpose and level of treatment: (1) reduce toxic constituents below hazardous levels; (2) meet water quality objectives for surface water discharge; (3) reduce toxic constituents below wildlife risk level, (4) purify water for marketing.	DWR Selenium Removal Using Activated Carbon. DWR/Univ. of Southern Illinois Selenium Removal from Agricultural Drainage Water Using Solid Adsorbants. **DWR** Prop 204-2000, 2001 Water and Salt Recovery through Solar Distillation.	None	Technology is under development, requires funding, ultimate brine or solid phase waste disposal	Research results are promising, as water supply becomes limited cost of treatment may become feasible
*Continue research and development to improve membrane technology and conduct economic assessment.	**USBR/PDD** Reverse Osmosis Project. **DWR/UCLA** Membrane Treatment of Agricultural Drainage Water.	**USBR** intends to study RO and membrane treatment. **DWR** Full Scale Demonstration of Agricultural Water Recycling Process Using Membrane Technology. **CALFED/DWQP/ ERP/PDD** Nanofiltration pretreatment to RO, Prop 13 NPS	High costs, lack of funding, energy requirement, brine disposal environmental issues**.**	Technology exists, treatment produces new water.

Drainage Treatment actions developed by SJVDIP in 2000. Treatment is the key to solution of environmental problems associated with agricultural drainage. Development needs to continue on all feasible and promising means of drainage treatment.	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Develop integrated biological, chemical, and physical treatment technology for cost-effectiveness.	**DWR** Prop 204-2000 Buena Vista Desalination Pilot Demonstration. **USBR/CALFED** support of desalination project at PDD.	**CALFED/DWQP/ PDD** Scaling Up ASBR	Lack of funding and brine management or disposal strategy.	Large pilot projects exist. Refinements in pretreatment process should receive funding.
*Continue to develop flow-through wetlands as treatment to reduce selenium from drainage to compliance levels without increasing the net biological risk.	**USBR** Supports studies of selenium removal at BWD. **UC** Selenium removal and mass balance in a constructed flow-through wetland system. **UC** Fate of selenium in flow-through constructed wetlands treating agricultural tile-drainage water. **UC Prop 204-2002** Removal of Se in lined reduction and open oxidation canals: a field study.	DWR/BWD project.	Possible accumulation of selenium and wildlife impacts.	There is desire and interest because it is not a complex technology and suited to on-farm activities.
*Continue advanced research and development of algal and bacterial bioremediation in selenium volatilization from evaporation ponds.	**DWR/SWRCB/UCD** 2000 (General Fund) Reducing Selenium Loads and Ecotoxic Risk in IFDM Systems Using Solar Evaporator Basins that Combine Invertebrate Harvest with Algal Volatilization of Selenium. **UC** Mitigating selenium ecotoxic risk by combining foodchain breakage with natural remediation.	None	Volatilization rate is low. Technology is under development. Lack of funding.	Will not require selenium disposal.

Drainage Treatment actions developed by SJVDIP in 2000. Treatment is the key to solution of environmental problems associated with agricultural drainage. Development needs to continue on all feasible and promising means of drainage treatment.	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Continue research and development of volatilization methods from soils and plants, and brine.	UC projects on plant Se volatilization..	None	lack of funding, low rate of volatilization.	Support research at existing projects such as Red Rock Ranch and Panoche Drainage District.
*Continue research and development of biological selenium precipitation.	**DWR/PDD/UCB/CALFED** Drinking Water Quality Program-funded Algal Bacterial Selenium Removal Facility. **USBR** support for ABSR treatment in PDD.	Ongoing	Brine or solid phase waste management and its costs.	Considerable work has been done and near completion.

Drainage Treatment actions developed by SJVDIP in 2000. Treatment is the key to solution of environmental problems associated with agricultural drainage. Development needs to continue on all feasible and promising means of drainage treatment.	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
To properly implement management of drainage and drainage-related problems, both the problems and the progress in solving them must be monitored. This is especially important because of the changing nature of the drainage problem and the flexible array of measures required for management. Monitoring all aspects of the problem and the effects of management will be critical to using the plan as a flexible guide to remedial actions.	**USBR** Monitoring of the Grasslands Bypass Project and the San Joaquin River. **USBR** Continued monitoring at Kesterson. **Grassland Area Farmers, CVRWQCB** monitoring of the Grasslands Bypass Project. Pond operators monitoring programs required under Waste Discharge Requirements. **UC** Transformation of selenium in Tulare Lake evaporation ponds (measurement of selenium speciation in the TLDD sediments). **UC** An investigation into the ecotoxicology of selenium bioaccumulation in birds. **UC** Chemical nature of selenium in agricultural drainage sediments and its implications for bioavailability.	Existing programs will continue. Monitoring at Red Rock Ranch will also continue.	Lack of a coordinated and funded monitoring program. Monitoring has not been part of the requirements of funded projects.	Coordinate agency-funded monitoring programs for technical and financial gain and efficiency. Incorporate monitoring and reporting requirements in all agency-funded projects.

River Discharge

The San Joaquin River has historically provided essential drainage for both agricultural land and managed wetlands in the Grassland Basin of the San Joaquin Valley. The Grassland Basin is comprised of several agricultural water and drainage districts, several federal and state managed wildlife refuges, and a large area of private duck clubs. To the south, the Tulare and Kern Basin region of the San Joaquin Valley has no outlet to the San Joaquin River, except in times of extreme flood. The drainage water typically contains high concentrations of dissolved solids, and some trace elements, particularly selenium and boron. Most of the selenium and boron load contained in drainage water originates from resident groundwater displaced into drain lines by infiltrating irrigation water. Groundwater concentrations of salts and trace elements are generally considerably higher than the leachate concentrations. The major water quality problems in the San Joaquin River are caused by the high loadings of salt, selenium, and boron in the displaced groundwater discharged to the River. In addition to the constituents listed, nutrients, sediment, and organic carbon that may originate from drainage are primary constituents of concern to CALFED for drinking water quality purposes, Drinking water purveyors, consumers and industry may be affected by these constituents thorough increased treatment costs.. Water quality objectives have been developed to protect fish and wildlife, to protect riparian agricultural irrigation diverters in the South Delta, and to protect municipal and industrial water users that divert water from the Delta.

In evaluating the consequences of discharging drainage water into the San Joaquin River, ecotoxicity of selenium compounds probably constitutes the most complex issue. The large gaps in knowledge have their roots in the extensive biogeochemical transformation and bioaccumulation of selenium. These research gaps were addressed in the 1999 “Peer Consultation Workshop on Selenium Aquatic Toxicity and Biocumulation” held by the U.S. EPA. The consensus opinion from the nine-member panel was that waterborne selenium concentration is not always a reliable indicator of selenium adverse effects on the aquatic top predators. This is because selenium exposure and effects in top predators (the major concern for selenium contamination) is mainly mediated through diets, i.e. the food chain organisms in which biotransformation and bioaccumulation occur. The consensus opinion emphasizes that the sediment and its resident food-chain organisms are major sinks for selenium bioaccumulation and biotransformation. Since these biogeochemical processes are very complex, they may be highly variable from site to site, leaving the need to address selenium impact on a site-by-site basis.

The 1990 Management Plan developed by the San Joaquin Valley Drainage Program recommended a number of drainage management measures to be implemented in the Grassland Basin, including source control (reduction in applied irrigation water), reuse of drainage on salt tolerant plants, small area of evaporation ponds, land retirement, and groundwater management. The report also recommended a continuation of limited discharge of drainage to the San Joaquin River, while meeting water-quality objectives, specifically for selenium and boron at Crows Landing. The discharge was to be conveyed to the River in a reopened portion of the San Luis Drain with an extension to the San Joaquin River below its confluence with the Merced River, for the purpose of maximizing the benefit of the dilution capacity of the Merced River inflow.

Since 1990, local growers have made advances in drainage reduction through source control. Drainage discharged from agricultural lands passed through a network of channels in the Grassland wetlands to Mud Slough North and Salt Slough to enter the San Joaquin River. Starting in 1996, implementation of the Grassland Bypass Project has consolidated agricultural subsurface drainage flows on a regional basis, and reopened a portion of the San Luis Drain to redirect drainage flow from the wetland areas to Mud Slough (north) and then the SJR, thereby removing subsurface drainage from all but Mud Slough North. The Grassland Bypass Project specifies selenium load limits on monthly and annual basis with the specification that annual selenium loads be reduced by 5 percent each of project years 3 through 5. Selenium load limits effectively eliminates use of assimilative capacity of the River and therefore extension of the San Luis Drain to below Merced River.

River Discharge actions developed by SJVDIP in 2000. Continue drainage discharge to the River while meeting water quality objectives.	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Development should continue on a water quality forecasting system, improved cooperation among water users, coordination of water operations, and a drainage management strategy that will allow full participation in a continuous real-time management system.	**CALFED and DWR Prop 204 2002** funding for real-time drainage discharge management project.	**DWR** plans to further develop a real-time project. DWR- Prop 204 real-time management project	Real-time management may not be applicable to selenium. Coordination among dischargers and diverters is needed.	A model has been developed. There is interest in the grasslands area to work with others to implement real-time management. Real-time management can work for salinity. It can be part of the GAF long-term drainage planning.
*A demonstration should be made that real-time management is at least as protective of the environment as the current load-based limits, and changes in the current regulatory limits on selenium discharges should be sought.	None	None	Total Maximum Daily Load for Se and B limits the real-time discharge management option.	There may be some relaxation for salinity
*Continue efforts on salinity water quality forecasting system by enhancing forecast accuracy and reliability and expanding information delivery systems.	**CVRWQCB** forecasting model	DWR real-time management	Funding.	The monitoring network exists and could be improved. Data communication can be improved.
*Continue efforts to gain support for a real-time management system for salt, boron, and molybdenum by tailoring the system design to the operational needs of users.	None	None	TMDLs may limit the real-time management of b and mo.	Continue to improve the existing real-time management model and monitoring programs. GAF long-term drainage management planning could consider it.

River Discharge actions developed by SJVDIP in 2000. Continue drainage discharge to the River while meeting water quality objectives.	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Develop continuous selenium and boron sensors for use in the SJR and tributaries. New sensors need to be developed that will enable continuous monitoring of selenium and boron concentrations in the San Joaquin River and tributaries to facilitate a real-time drainage discharge management system.	None	None	Selenium has different forms and detection by sensors may not be a feasible option.	Improving sample collection and increasing sampling frequency and a more rapid sample analysis may provide data.
*Research should be continued on the determination of site-specific ecotoxicity criteria for selenium based on a better understanding of exposure pathways for at-risk biota, and the development of concentration-based regulatory criteria that would allow for real-time management of selenium discharge.	**SWRCB/UCD** 2000 (General fund) Development of Ecotoxic Indicators in Fish for Se TMDL Regulation in San Francisco Bay-Delta and San Joaquin River	None	Requires further research.	Work on this topic has begun.

River Discharge actions developed by SJVDIP in 2000. Continue drainage discharge to the River while meeting water quality objectives.	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Develop a better understanding of sediment biogeochemistry, organoselenium pathways, and selenium assimilatory capacities in order to develop temporal site-specific criteria that accurately reflects the bioaccumulation and toxicity of selenium speciation in the food chain. The long-term ecosystem effect of selenium is another area for study. Refining methods of separating Se from wildlife food chain is needed.	**SWRCB/UCD** 2000 (General fund) Development of Ecotoxic Indicators in Fish for Se TMDL Regulation in San Francisco Bay-Delta and San Joaquin River	None	Requires further research.	Work on this topic has begun.
*Continue to upgrade biota toxicity testing.	Grassland area farmers and USFWS monitoring	Ongoing	Lack of funding.	May provide valuable information to better manage the river for both discharge and protecting the river's ecological functions.
*Continue and expand support of essential water quality and flow-monitoring stations along San Joaquin River and tributaries.	**USBR/RWQCB/DWR** Fund/support SJR monitoring	**USBR** plans to expand monitoring programs. DWR real-time management	Funding.	Agencies are involved. Include monitoring requirement in agency-funded projects.
*Develop site-specific selenium water quality objectives as alternative compliance requirements.	None	None	This is a regulatory agency function.	May be a part of GAF long-term drainage management planning.

River Discharge actions developed by SJVDIP in 2000. Continue drainage discharge to the River while meeting water quality objectives.	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Support selenium and mass balance studies to measure sources and sinks in aquatic ecosystems.	**DWR/UC Davis.** Microphyte-Mediated Selenium Biogeochemistry and its Role in Bioremediation of Selenium.	None	Requires data collection.	Monitoring for mass balance studies can be done on existing projects.
*Conduct monitoring and research on the long-term effects to the SJR and Delta ecosystems of selenium from drainage.	Water quality data is available for some locations, but no specific study is planned for this purpose.	None	Data collection is inadequate for the program.	Move from monitoring to toxicological based understanding of selenium and what are safe levels. Seek CALFED funding
*Seek changes in the regulatory limits placed on selenium discharges.	None	None	Data is needed that the discharge can be protective of the river.	Move from monitoring to toxicological based understanding of selenium and what are safe levels.
*Re-evaluate selenium chronic water quality criteria.		EPA ongoing	-	EPA is scheduled to reevaluate.
*Continue developing drainage control and management strategies, including source control, drainage reuse, drainage treatment, etc., that will allow full participation in a continuous real-time management system.	**USBR/Grasslands Area Farmers**, long-term plan for use of Grasslands Bypass. **DWR** Prop 204 In-Valley Drainage Planning.	Ongoing	Without disposition of salts, these approaches may not be sustainable. Presently technology for brine management is not cost-effective and disposal is unacceptable.	Technical and financial support to find alternatives for using or disposing of salts and brine.

River Discharge actions developed by SJVDIP in 2000. Continue drainage discharge to the River while meeting water quality objectives.	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Work needs to continue on the refinement of computer models that can assist in developing drainage control and management strategies that will optimize the integration of source reduction, drainage reuse, and drainage treatment in a continuous real-time drainage management system.	Ongoing work	Ongoing	Requires coordination	Models for true salt budget for on farm, district and regional scales needs to be developed, including sub surface flow for better management of the system.
*Support for boron mass balance studies that are also needed to determine boron sources and sinks in the ecosystem, and the sub-lethal and chronic impacts of boron on fish and other aquatic species. Conduct the studies.	None	None	Lack of funding and research.	CALFED funding
*Conduct research on the effects of sulfate salinity on Chinook salmon smolts in the San Joaquin River.	None	None	No funds	CALFED funding.
*Develop innovative measures to decrease discharges of boron, molybdenum, and salt.	Grassland area farmers approach to the bypass	Ongoing	Uncertainties	GAF drainage plan
*Design and construct wildlife-safe drainage holding ponds to facilitate real-time management.	None	None	Uncertainties	Coordination

River Discharge actions developed by SJVDIP in 2000. Continue drainage discharge to the River while meeting water quality objectives.	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Evaluate feasibility of extension of the San Luis Drain downstream of the Merced River.	Grassland Area Framers are required to develop a long-term plan for drainage discharge by 2006	None	TMDL for Se and B may limit this work	GAF drainage planning

Salt and Selenium Utilization

Both salt and selenium have essential and established beneficial uses in industry, and for selenium, an essential nutrient in animal nutrition. Many areas of the world, including parts of California, suffer from a deficiency of selenium. Problems associated with salt and selenium utilization then become ones of separation and distribution, not disposal. An evaluation of these elements as resources rather than pollutants is therefore justified.

The composition of drain water salt differs from that of seawater. Whereas seawater contains primarily sodium-chloride salt, drain water from the westside San Joaquin Valley typically contains sodium-sulfate salt. When drain water is concentrated by evaporation, the dominant minerals that precipitate are thenardite (sodium sulfate), halite (sodium chloride), gypsum (hydrated calcium sulfate), and calcite (calcium carbonate). The drain water also contains several trace elements of concern: selenium, arsenic, boron, and molybdenum. During the evaporation process, those elements will associate with, or become incorporated into, the precipitated mineral salts. Such contamination of the salt minerals may have positive or negative implications, depending on the intended use of the salt.

The commercial utilization of sodium sulfate includes dying of textiles, glass making, glazing and other industrial uses. For certain commercial and industrial uses, salt must first be purified. For example, in the sodium-sulfate industry, purity exceeding 90% may be required. The U.S. market for sodium sulfate is about 1.5 million tons per year. However, as of 1989, the combined annual deposition of salt in evaporation ponds in the San Joaquin Valley was an estimated 0.8 million tons per year. The harvesting and marketing of that much sodium sulfate could drive down the price, possibly to levels so low that it would become uneconomical to harvest the salt. Transportation must also be considered in planning to utilize San Joaquin Valley salt. The cost of freighting the harvested material to a salt refinery or other market must be low enough to provide a profit. In general, impurity of salts harvested from

drainage, costs of salt purification, and costs of transportation are major obstacles for salt marketing,

Collection of water in solar evaporators facilitates the harvesting of salt. Thus, the feasibility of using solar evaporators, as previously discussed, is relevant to the goal of salt utilization. Indeed, if significant commercial markets were established for the utilization of the salts, it would provide an economic incentive to work towards the utility of solar evaporators.

Considering that 2-3 million tons of salt influx per year by irrigation water (in addition to significant amounts of salt mobilized from soils as a result of irrigation) needs to be disposed of to maintain salt balance in the Valley, even an optimistic estimate of the amount that could be commercially marketed would represent a small percentage of the total salts to be disposed. Active pursuit for commercial utilization of the salts and selenium is justified, and it will require all the other options for separating the salts from productive agricultural fields, however the salt utilization approach should not negate pursuit of other salt disposal options such as disposal in lined storage facilities or ocean disposal.

Salt and Selenium Utilization actions were developed by SJVDIP in 2000.	Existing, On-going Projects that were initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Continue research and development for methods and technologies of separating salts and trace elements from drainage water.	**DWR** Prop 204-2000 Buena Vista Desalination Pilot Demonstration. **DWR** Prop 204-2000 Investigate and Evaluate alternative systems of salt separation, purification, utilization, or disposal.	Ongoing	Costs and lack of funding	IFDM projects and Panoche Drainage District projects.
*Continue research on environmentally safe and economically feasible end points for salts.	**DWR, USBR** solar ponds. **USBR** drainage reevaluation. **UC Prop 204 2002** Characterization and utilization of saline biomass.	Ongoing	High costs and environmental impacts and lack of funding.	USBR San Luis Drain Planning
*New or adaptive techniques for the efficient means of separating salts from soils and drainage water in evaporation systems and achieving the necessary degree of purity for commercial marketing and utilization need to be developed.	**DWR** Prop 204-2001 Water and Salt Recovery by Solar Distillation.	Ongoing	Limited market	Research
*Design, construct, operate, and evaluate a mobile carbon aerogel capacitive deionization (CDI) desalinization process unit.	Metropolitin water district.	None	Costs	Research
*Develop a research and development program for harvesting, purifying, manufacturing, and marketing of farm-based salt and selenium products.	**DWR/UC Davis** Prop 204- 2000 Salt Utilization in Glass Making and textile. **CALFED - DWR/UCD** salt harvesting project.	Ongoing	Limited market	Ongoing research will provide needed information.

Land Retirement

The purpose in including land retirement in the 1990 Management Plan was a means to isolate lands with relatively high concentrations of selenium in the soil and shallow groundwater. Other benefits of land retirement have since gained importance. Water that would have been applied for irrigation becomes available for other uses. Retired land could become suitable as wildlife habitat for upland endangered species. The nature of the restored habitat is partially dependent on land management. A whole range of scenarios could be considered based on the type and level of adaptive land management and management costs.

As a voluntary program, lands most likely to be retired have very low agricultural economic return because of existing high water tables and salinized soil and water resources. The lands are typically located at the lower elevations near the trough of the Valley. Water tables would be expected to drop under lands not irrigated. However, depending on precipitation and lateral flows into the area, water tables could be maintained at a depth close enough to the surface that water would move by capillary action to the surface and evaporate. Upward water flow would carry salts and toxic elements such as selenium to the surface and deposit them through evaporation. This would lead to land with sparse vegetation, wind erosion, and poor quality and possibly toxic habitat. Therefore, one of the major questions related to the land retirement option is whether the water table would be deep enough to prevent salinization and selenification of the soil surface. Some retired lands could require ongoing management, such as pumping of groundwater, to prevent soil salinization caused by saline groundwater entering the site from below, adjacent, or up-slope areas. Otherwise, lands taken out of agricultural production could loose environmental quality and future value, including for wildlife habitat. . A site-specific adaptive habitat management plan should be developed for each retired parcel that explicitly states the goals and objectives for that parcel, and includes protocols that address specific revegetation and monitoring needs and possible negative impacts.

The socio-economic impact on local communities of the lost revenues and jobs must be counted as part of the cost of retiring a parcel of agricultural land. Substantial direct costs may be involved in the purchase of the land for retirement, and monitoring and management of the land after retirement. Restoration for wildlife habitat will incur additional costs.

A number of land management measures and alternative strategies to permanent land retirement and complete cessation of irrigation could achieve the same objectives of source reduction and reduced drainage volume, while minimizing or avoiding soil salinization and reduced plant growth. Alternative measures and strategies include the systematic implementation of rotational-, distributed-, or periodic-fallowing programs and pumping of groundwater for reuse as limited irrigation of winter crops to counter the upward transport of salt from shallow groundwater to the soil surface, while providing plant growth opportunities for both agricultural and upland wildlife habitat uses.

Land retirement does not allow continued agricultural productivity, but it does free surface water supplies for other uses, and reduce or eliminate the need to dispose of drainage water from retired land. The long-term consequences of land retirement depend upon what type of adaptive land management is adopted.

Land Retirement actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Develop guidelines for restoration of native plant communities on retired land to provide important habitat for the recovery of special-status species in the San Joaquin Valley.	**USBR** land retirement program.	Ongoing	Management of retired land and potential impacts.	Demo project can lead to development of guidelines.
*Hydrologic and soil modeling studies indicate that without implementation of special management techniques, retired lands could become excessively salinized and seleniferous. Develop guidelines for soil and vegetation management.	Many done	None	Models are not comprehensive and need refinement.	USBR land retirement program.
*Research needs to continue on land management strategies for retired lands that will minimize impacts from salinization and selenification of the soil, and will optimize post-retirement land use for wildlife habitat or other uses.	**USBR** land retirement program. **USBR** drainage reevaluation.	None	Lack of funding	Include in land retirement program

Land Retirement actions developed by SJVDIP in 2000	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*A number of land management strategies exist as an alternative to complete cessation to irrigation and permanent land retirement that could still achieve the objectives of increased water conservation and reduced drainage volume while minimizing soil salinization. Select alternative management strategies as necessary to avoid degradation of natural resources.	**BWD/PDD** Grasslands Integrated Drainage Management Project.	None	Doesn't permanently eliminate source of selenium.	May be desirable where temporary land retirement is feasible.
*Evaluate feasibility of land retirement under each specified criteria.	Done for each project	None	None	CEQA/NEPA
*Continue the USBR Land Retirement Program.	**USBR** Land Retirement Program. Demonstration Project in the Tulare Lake Area.	Ongoing	Funds	Support WWD program
*Develop WWD land and water rights acquisition program.	**Westlands Water District** on-going project.	Ongoing	District responsibility	WWD program
*Collect detailed, site-specific, and current soil and groundwater data from retired land sites.	**USBR** Land Retirement Program.	None	Costs	Incorporation into land management plans
*Analyze impacts of the transfer or reallocation of retired land water rights.	Done for each project	None	Costs	CEQA/NEPA

Land Retirement actions developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Identify regional objectives, formulate land retirement scenarios, and evaluate short- and long-term consequences.	Wes Wallender-UC Davis work on land retirement scenarios impact of groundwater quality and quantity.	None	No action	CALFED ROD commitment to retire land.

Ground Water Management

High water tables and substantial drainage volumes are the direct result of an imbalance in regional groundwater budgets. When recharge rates exceed the groundwater system capacity to discharge via subsurface lateral flow and flow to wells, water tables consequently rise until intersecting drains or the topographically lower portions of basins.

Regional groundwater budgets must be altered to reduce drainage volumes. Modeling studies show that this can be accomplished through a combination of reductions in groundwater recharge and increases in groundwater pumpage. Reductions in recharge can be accomplished by reducing deep percolation through source reduction, crop use of shallow groundwater, and land retirement. The notion in recent years that the increases in pumpage would have to come from the semi-confined aquifer or from new wells drilled specifically for water table management is incorrect. Regional groundwater models and basic hydrogeologic principles demonstrate that increased pumpage can occur in existing wells. Further, allocating a significant portion of that pumpage to wells tapping the sub-Corcoran confined aquifer can be quite effective for lowering the water table regionally. This occurs by inducing increased rates of downward leakage regionally across the Corcoran clay. Increased pumpage would have the benefit of providing increased water for irrigation and decreased demand for existing surface water supplies.

In view of regional modeling studies that elucidate groundwater system processes, the notion in recent years that the groundwater management option should be implemented locally or only as a short-term solution is no longer appropriate. It is now clear that if local or regional drainage volumes are to be significantly reduced, long-term regional groundwater management is necessary. This strategy alone would significantly alter the regional groundwater budget that ultimately controls water table elevations. Some local implementation of groundwater management can perhaps affect water table elevations locally, but the net impact of such a strategy would be negligible regionally.

In general, concentrations of both dissolved solids and trace elements decrease with depth in the semi-confined aquifer overlying the Corcoran clay layer. Better water quality is found in the confined aquifer system under the Corcoran clay layer. Pumping the better quality water from deeper wells causes a downward movement of the poorer quality water found at shallower depths. Plants extract the water resulting in a high salt concentration in the water leaving the root zone. In practice, good water quality is extracted by pumping and replaced by poor quality water percolating below the root zone causing a gradual depletion of the good quality groundwater supply. Presently, groundwater pumping is increased during drought years when surface water supplies are limited. Exploiting the supply of good quality groundwater decreases the opportunity to reduce the impact of drought by increased pumping in future years.

Increasing the groundwater pumping rates would accelerate the ongoing, downward movement of poor quality groundwater. Because this process will occur even without increases in pumpage, it is not clear whether the relative water quality impacts would be significant. Groundwater quality at some, local supply wells would probably be impacted on a ~10-yr time scale rather than, say, a ~20-yr time scale. Regionally, however, the "life" of the aquifer in terms of groundwater quality would be on the order of a century or more.

Several state laws prohibit degradation of groundwater, with exceptions being made in rare instances where the degradation is deemed beneficial to the people of California. Proactively managing groundwater resulting in accelerated groundwater quality degradation would require such an exception, but would be consistent with the fact that groundwater quality degradation is already occurring under present pumping practices in the San Joaquin Valley.

Regional groundwater analyses indicate that increases in pumpage can significantly lower the water table without creating excessive risk of inducing land subsidence (i.e., without dropping confined aquifer water levels below historical lows).

Significant improvements in monitoring of groundwater quality, groundwater levels, pumpage, and subsidence are needed to support implementation of the groundwater management option in an adaptive framework. Even if a groundwater management option is not adopted, such information is necessary for basic stewardship of water resources in the basin.

Groundwater management actions were developed by SJVDIP in 2000	**Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities**	**Future Planned Projects for 2002-03 and beyond by various entities**	**Constraints (technical, financial, institutional, and environmental) to move forward**	**Opportunities (implementability, desire, incentives, waivers, etc.) to move forward**
*Continue to support both shallow and deep groundwater monitoring and distribution of data to growers for improved groundwater management.	**DWR/USBR/Districts** Monitoring program.	**USBR** has supported studies of GWM concept in the Grasslands Area	Costs	Water quality monitoring
*Support district-level groundwater data collection and groundwater evaluation actions.	Ongoing district programs.	Ongoing	Costs	Local funding
*Develop planning models, incentive and support programs, workshops, where feasible to encourage groundwater management.	A number of models exist	None	Costs	Funding local plans
*Increasing groundwater pumping will potentially accelerate the downward movement of shallow, high salinity water, which as planned aquifer degradation may present an institutional and regulatory hurdle. Conduct feasibility studies to develop an appropriate groundwater management project.	**USBR** feasibility study for grassland area.	None	May violate SWRCB water quality policies	Feasible for certain areas.
*Establish groundwater management agency, develop management plan and gain plan approval.	Similar agencies exist	None	Needs district support.	District initiative

Groundwater management actions were developed by SJVDIP in 2000	Existing, On-going Projects that initiated or were completed after 2000 by State, federal, local agencies and universities	Future Planned Projects for 2002-03 and beyond by various entities	Constraints (technical, financial, institutional, and environmental) to move forward	Opportunities (implementability, desire, incentives, waivers, etc.) to move forward
*Continue existing groundwater pumping contributing to lowering of shallow groundwater levels.	No action needed.	None	Groundwater extraction for a variety of purposes is occurring on a nearly continuous basis, however, it is secondary to surface water supplies due to higher costs and poor quality. Another constraint is the possible degradation of aquifer.	Groundwater Management Plans.