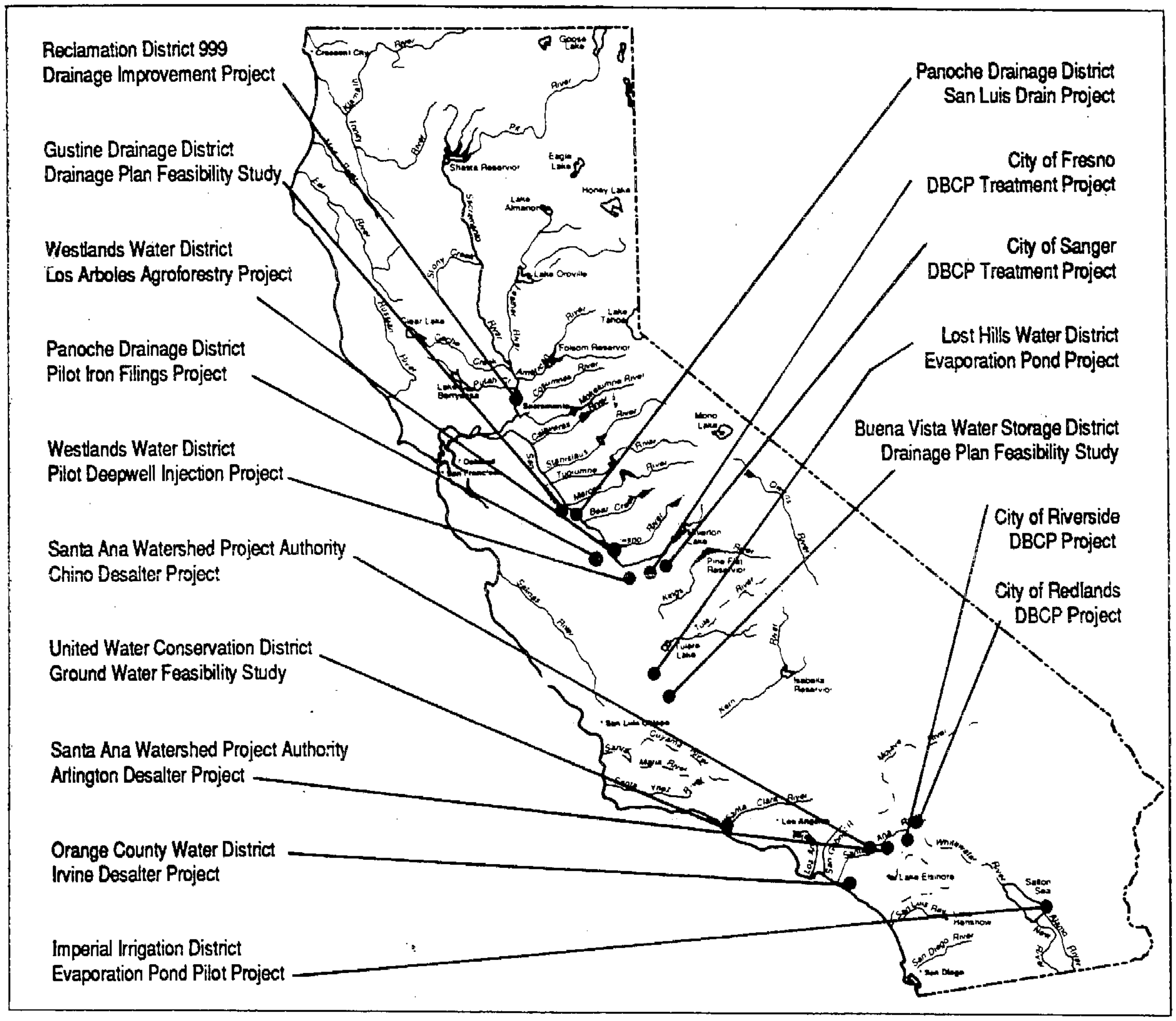

1990 ANNUAL REPORT AGRICULTURAL DRAINAGE WATER MANAGEMENT LOAN PROGRAM

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Executive Summary

In the early 1980's, serious environmental damage occurred at Kesterson Reservoir through the uncontrolled discharge of agricultural drainage water. In response to the critical need for agricultural drainage water management facilities, the people and Legislature of California enacted AB 1982, the Water Conservation and Water Quality Bond Law (Bond Law) of 1986. The legislation created the Agricultural Drainage Water Management Loan Program (Loan Program), and authorized the sale of $75 million of state general obligation bonds to finance low-interest loans to public agencies for agricultural drainage water management projects and related feasibility studies. The Loan Program is administered by the State Water Resources Control Board (State Board).

Section 13467, Chapter 6.1 of Division 7 of the Water Code requires an annual report to the California State Legislature on the status of the Loan Program and the status of agricultural drainage problems on a statewide basis. This report is the fourth in a series of annual reports to the Legislature.

Discussion of the status of agricultural drainage problems in previous reports was centered mainly on the characterization of regional and statewide drainage problems. The focus in this report is on mitigation opportunities for agricultural drainage problems.

Chapter I of this report discusses the status of the Loan Program. Chapter II discusses mitigation measures for agricultural drainage problems. Major findings of the report are as follows:

First, thirteen projects totalling $46.7 million have been approved for funding by the State Board. There are four other active projects in the Loan Program totalling $51.9 million; however, funding will only be available for $24.5 million. The State Board will continue to approve eligible projects on a first-come, first-served basis when they are ready to proceed until Loan Program funds are fully committed.

Second, large areas on the west side of the San Joaquin Valley are impacted by agricultural drainage. In-valley drainage management options for this area are source control, treatment/removal, disposal, and institutional/jurisdictional. In-valley alternatives do not offer a long-term solution to the drainage problem, and some means of salt removal from the valley is necessary for sustained agricultural production in this area.

Chapter I.

STATUS OF THE AGRICULTURAL DRAINAGE WATER MANAGEMENT LOAN PROGRAM

PROGRAM DESCRIPTION

Loan Provisions

The interest rate on loans under the program is one half of the interest rate paid by the state on the most recent sale of general obligation bonds. The maximum loan amount is $20 million, and the maximum loan term is twenty years. Some specific types of facilities identified in the Bond Law as eligible for funding include surface impoundments such as evaporation ponds, conveyance facilities, treatment works (including ion exchange, desalting technologies, and biological treatment), and injection wells.

Agencies seeking loan funding must complete project planning before their projects are submitted for State Board approval. For design and construction projects, this generally includes the following:

* Compliance with the California Environmental Quality Act (CEQA) must be demonstrated. This is usually accomplished through the circulation and adoption of an Environmental Impact Report (EIR) or Negative Declaration.

* Waste Discharge Requirements (WDRs) or waivers from WDRs issued by the appropriate Regional Water Quality Control Board (Regional Board) are required for some projects. This requirement may also be met by the submission of Drainage Operation Plans to the Regional Board for some projects. Other appropriate permits must also be obtained.

* A facilities plan must be submitted to the State Board. This is not project design but a description of the nature and scope of the proposed project and project alternatives, including estimated costs.

Planning costs are not reimbursable under the Loan Program. These include the costs of filing the application, preparing the facilities plan, or complying with CEQA. Most other project related costs are eligible, such as costs of design and construction, and project related engineering, legal, and administrative costs. Right-of-way and land purchase costs are also eligible.

Loan Processing Procedures and Guidelines

Several steps are involved in the loan funding process. It typically takes from one to two years from the date of first application for a project to be funded. Following are some of the major steps in the loan funding process:

1. Interested agencies submit applications and begin project planning.

2. The State Board reviews applications and requests additional information, when necessary.

3. A draft statewide priority list of projects is established in conjunction with the Regional Boards and the State Board's Clean Water Strategy (CWS) staff.

4. The draft priority list is submitted for State Board approval.

5. The priority list is revised as necessary and adopted by the State Board.

6. Agencies complete project planning and submit planning documents for review.

7. Eligible projects from the priority list for which planning is complete are submitted for State Board approval.

8. Legislative approval is requested for projects approved by the State Board.

9. Public hearings are held on the proposed projects, if required by the Legislature.

10. Loan contracts for approved projects are negotiated and signed.

11. Disbursement of loan funds may take place after approval of the loan contract by the State Department of General Services.

12. Completed plans and specifications are submitted to the State Board Project Manager for review.

13. Annual loan repayments begin one year after completion of construction or two years after loan contract execution, whichever occurs first.

Types of Projects Being Funded

Twenty-six loan applications are on file with the State Board. The projects can be broadly classified into five categories as follows:

1. Treatment projects - Projects in this category may involve physical/chemical processes or biological processes for removal of contaminants in drainage water. Loan applications have been received for two projects for removal of selenium.

2. Containment projects - These projects may achieve pollution control through means other than the construction of treatment or disposal facilities. Projects in this category may involve improvements or modifications to conveyance facilities or

changes in operational or managerial procedures. Agroforestry projects are considered containment projects. There are two projects in this category.

3. Disposal projects - This category includes evaporation ponds and deep well injection facilities. Loan applications have been received for eleven disposal projects, including three inactive projects which may be developed as either disposal or selenium removal projects.

4. Groundwater cleanup projects - These projects may involve desalting technology, nitrate removal, or treatment for dibromochloropropane (DBCP). Groundwater cleanup projects are treatment projects as described above, but are sufficiently distinct to warrant a separate category. There are seven active projects in this category. All will produce potable quality water.

5. Feasibility studies - These may include studies of projects in any category discussed above, or may be investigations of drainage problems without fixed solutions. Loan applications have been received for four feasibility studies.

1989-90 PROGRAM ACTIVITY

Assembly Bill 583

State Board approval was obtained for one project in 1989, a feasibility study for Buena Vista Water Storage District. Loan funds will be used to evaluate a high water table within the district. Thirty-five shallow monitoring wells will be installed to sample and monitor ground water levels and water quality parameters. Results of the study will be used to establish an agricultural drainage program for the district. Legislative approval for this project was obtained via Assembly Bill 583.

New Applications

The Loan Program has been continuously open for receipt of new applications since February, 1989. Three new applications have been received since the 1989 priority list was adopted totalling $26.3 million. These are:

1. Westlands Water District - Los Arboles Agroforestry Project, $19,121,000

   This project is being designed to dispose of 2000 acre-feet per year of subsurface drainage water produced from a 4000-acre area south of Mendota. Drainage water from this area is high in salinity (9000 ppm), selenium (0.35 ppm), and boron (15 ppm). The drainage water will be used to irrigate 600,000 eucalyptus trees in six parcels totalling 480 acres. Concentrated drainage from the eucalyptus will be used to irrigate 120 acres of salt tolerant plants which will further reduce the drainage water volume to a range of one-fourth to one-ninth its original volume. Three alternatives are being considered for final brine disposal: (1) crystallization in small evaporation ponds (60 total acres), (2) conveyance to a cogeneration facility for thermal evaporation, and (3) conveyance to the district's deepwell injection facility. Eucalyptus will be harvested as biomass for fuel or pulp fiber, and will offset some of the project costs. The salt tolerant plants may also have some commercial value as cattle feed.

2. City of Fresno - DBCP project, $4,008,000

   Fresno is one of several cities in the San Joaquin Valley dependent on ground water for its municipal supply, and whose ground water has been contaminated with DBCP. In 1989, the California Department of Health Services lowered the Maximum Contaminant Level (MCL) for DBCP from 1.0 ppb to 0.2 ppb. As a result, many of the city's wells have been removed from service. The proposed project would retrofit five city wells producing 13 mgd with granular activated carbon treatment facilities. These wells are in critical areas and have been selected to not only treat the contamination in the immediate area, but to intercept contaminant plumes before they migrate to other city wells. Spent carbon from the reactors will be regenerated off-site.

3. City of Sanger - DBCP Project, $3,215,000

   The City of Sanger is located southeast of Fresno and also depends on ground water for its municipal supply. Eight of eleven city wells producing 5 mgd are contaminated with DBCP in excess of the MCL. DBCP concentrations in these wells range from 0.25 to 3.3 ppb. The proposed project will provide well head treatment facilities for these wells to bring them into compliance with the MCL.

These projects were added to the Loan Program priority list on June 21, 1990.

PROJECT STATUS

Project Summaries

As described previously, a number of steps are required in proceeding from the initial application to the disbursement of loan funds. The twenty-six projects can be classified as to their progress in the application process as follows:

Projects with loan funds disbursed:

* Santa Ana Watershed Project Authority - Arlington desalter
* Panoche Drainage District - Iron filings selenium removal feasibility study
* Reclamation District No. 999 - Drainage facilities project
* Gustine Drainage District - Drainage plan feasibility study

* Buena Vista Water Storage District - Drainage plan feasibility study
* United Water Conservation District - Ground water nitrate feasibility study

Projects with signed loan contracts, awaiting disbursement:

* City of Redlands - DBCP removal facilities
* Imperial Irrigation District - Evaporation pond pilot project
* Westlands Water District - Prototype deep well injection project

Projects with Board approval, awaiting loan contract execution:

* Lost Hills Water District I - Evaporation pond project
* City of Fresno - DBCP removal facilities (approved July, 1990)
* Orange County Water District (OCWD)- Irvine desalter (approved July, 1990)
* Panoche Drainage District - San Luis Drain project (approved conditionally, July, 1990)

Projects in planning stage, awaiting State Board approval:

* City of Riverside - DBCP removal facilities
* Santa Ana Watershed Project Authority (SAWPA) - Chino desalter
* City of Sanger - DBCP removal facilities
* Westlands Water District - Agroforestry project

Inactive projects not likely to proceed in 1990

There are nine inactive projects in the Loan Program. Some may be activated when the results of pilot-scale projects or feasibility studies are completed. Others are waiting for cost-effective treatment schemes to be developed for managing drainage water.

* Westlands Water District - Prototype biological selenium removal facility
* Westlands Water District - Large-scale deep well injection project
* Panoche Drainage District - Expanded iron filings selenium removal facility
* Broadview Water District - Selenium removal or deep well injection facility
* Charleston Drainage District - Selenium removal or deep well injection facility
* Pacheco Water District - Selenium removal or deep well injection facility
* Lost Hills Water District II - Evaporation pond and drainage system
* Dudley Ridge Water District South - Evaporation pond system
* Dudley Ridge Water District North - Evaporation pond system

Status of Drainage Account

Table 1 summarizes the status of the agricultural drainage water account for the seventeen active projects described above. These projects represent a net deficit to the Loan Program of approximately $27.4 million. Changes of the inactive projects to an active status could increase the deficit significantly.

Priority List

Table 2 is the 1990 priority list adopted by the State Board on June 21, 1990. The list has not been updated to reflect State Board action on the City of Fresno, Orange County Water District, and Panoche Drainage District III projects at the July, 1990 State Board meeting.

Six rating factors were used for the 1989 and previous priority lists. These included:

1. Severity of the water quality problem (Scale: 0-4, 4 = most severe).

2. Effectiveness of the proposed project as a solution to the water quality problem (Scale: 0-4, 4 = most effective).

3. Approach to the water quality problem, treatment versus containment or disposal (Scale: 0-4, 4 = treatment).

4. Applicant's readiness to proceed (Scale: 0-4, 4 = ready to proceed).

5. Economic feasibility of the proposed project (Scale: 0-2, 2 = economically feasible for the agency).

6. Technical feasibility of the proposed project (Scale: 0-2, 2 = technically feasible).

Section 13459(b)(5) of the Bond Law requires the State Board to give preference to projects which treat drainage water where the State Board finds that the technology is readily available and economically feasible for the agency. This requirement is reflected in factors 3, 5, and 6 above.

The State Board's Clean Water Strategy (CWS) priority rating system has been adapted for use in the preparation of the 1990 priority list, with some contribution from the historic ADLP priority rating factors. CWS input consists of a Resource Value factor, a Condition factor, and a Feasibility factor. ADLP rating factors for approach to the water quality problem and readiness to proceed were retained, but were scaled to conform to CWS conventions. Factors used for the current year are shown below. Statutory requirements are reflected in factors 3 and 4.

1. Resource Value (Scale: 1 - 5, 1 = greatest resource value).

2. Condition (Scale: 1 - 5, 1 = worst condition).

3. Feasibility (Scale: 1 - 5, 1 = most feasible).

4. Approach to the water quality problem (Scale: 1 - 5, 1 = treatment).

5. Readiness to proceed (Scale: 1 - 5, 1 = ready to proceed).

Projects on the 1989 priority list that have not been approved for funding have been re-evaluated using the new methodology. Two agencies on the 1989 priority list have withdrawn from the Loan Program and are not shown on the priority list. These are Tulare Lake Drainage District (evaporation pond project) and Colusa County Zone of Benefit No. 2 (feasibility study).

Eligible projects on the priority list are submitted for State Board approval on a first-come, first-served basis when the planning process is complete (environmental work, permits, facilities plan).

PROGRAM SUMMARY AND PROJECTIONS

Thirteen projects totalling $46.7 million have been approved for funding by the State Board. There are four other active projects totalling $51.9 million; however, funding will only be available for $24.5 million. The State Board will continue to approve eligible projects on a first-come, first-served basis when they are ready to proceed until Loan Program funds are fully committed.

Chapter II.

MITIGATION MEASURES FOR AGRICULTURAL DRAINAGE PROBLEMS

This chapter is adapted from the executive summary of a report entitled "Agricultural Drainage Problems in California: Mitigating Adverse Impacts" prepared by the University of California at Davis under contract with the State Board. The Principal Investigators are Blaine R. Hanson and Kenneth K. Tanji. Research Staff are Wil Bowers and Craig Woodring.

The terms "contamination" and "pollution" are used interchangeably in this section, and are not to be interpreted by the definitions given in Section 13050 of the Water Code.

BRIEF SUMMARY OF AGRICULTURAL DRAINAGE PROBLEMS IN CALIFORNIA

Irrigation of agricultural lands causes surface runoff and deep percolation or subsurface drainage. Surface runoff occurs when the application rate of the applied irrigation water exceeds the infiltration rate of the soil. Deep percolation occurs when the volume of infiltrated water exceeds the soil moisture deficit.

The primary hazard of surface runoff is suspended sediments in the water causing turbidity problems and contamination from nutrients and pesticides adsorbed to the suspended particles. Salinity of surface runoff generally differs little from that of the irrigation water, although salinity of surface runoff in the Imperial Valley can be slightly higher because of salt leaching during alternate-furrow irrigation.

The primary hazards of deep percolation or subsurface drainage are chemical dissolution in the soil, chemical transport to aquifers, and high water tables. Chemicals leached include nitrate, pesticides, other soluble salts, and trace elements such as selenium, boron, molybdenum, and others. Deep percolation transports these dissolved materials down to the aquifers, causing contamination of the groundwater. Deep percolation can also cause a rise in shallow water tables, such as along the west side of the San Joaquin Valley and in the Imperial Valley.

Nitrate pollution of groundwater is found in many areas in California. Those areas most significantly affected are the coastal valleys (Salinas Valley, Santa Maria Valley, portions of Santa Barbara County, and San Luis Obispo), the east side of the San Joaquin Valley, and southern California (primarily Chino Valley, Ventura County, Los Angeles County).

Pesticide contamination of groundwater is also a significant problem in the state. The Central Valley of California is substantially affected, with about 25% of the usable groundwater contaminated with DBCP. Ten pesticides in groundwater are currently associated with non-point source pollution from agriculture.

Salinity and associated trace elements are problems along the west side of the San Joaquin Valley and in the Imperial Valley. Both areas contain salt-affected soils, the result of saline shallow water tables. Toxic materials such as selenium, boron, molybdenum and others in the shallow groundwater compound disposal problems of drainage water.

Strategies for mitigating the adverse impacts of nitrate and pesticide pollution include improving irrigation water management, improving chemical management, and treating the contaminated water for domestic uses. Research has revealed that the amount of nitrate leached below the root zone depends on both the fertilizer and water application rates. Reductions in applied fertilizer and/or applied water can reduce leached nitrate. However, even if no more nitrate is leached, displacing existing groundwater with newer water may take decades. Thus, treatment of the groundwater for domestic purposes may be necessary to reduce concentrations to acceptable levels.

Strategies for avoiding or mitigating the adverse environmental impacts from toxic substances in subsurface drainage along the west side of the San Joaquin Valley include the following:

1. Improved management of irrigation water,

2. Use of saline water for crop production,

3. Treatment for removal of toxic materials, and

4. In-valley disposal.

The dilemma facing the valley is that these strategies may not be long-term solutions. Long-term sustainability of agriculture along the west side may require salt removal from the valley.

MITIGATING NITRATE AND PESTICIDE POLLUTION

Pollution Potential

Nitrate

Nitrate moves readily with water in soil, and is easily leached below the root zone. The potential for leaching of nitrate is greatest in sandy soils and smallest in clay soils. Research has shown that denitrification (a soil-based process which transforms nitrate into gases which escape into the atmosphere) can occur in finer-textured soils, which reduces the leaching hazard. Nitrate leached below the root zone is not likely to undergo significant denitrifcation.

Table 3 lists criteria for judging the relative sensitivity of areas to the leaching of nitrate. In general, excessive nitrate leaching can occur under the following conditions:

1. Crop conditions that create high potential for nitrate leaching.

    a. Nitrogen (N) removed in the harvestable portion of the crop is a small portion of the total N. About 25 to 35% or less is removed by fruit crops, about 35 to 45% or less is removed by vegetable crops, and about 45 to 60% is removed by grain crops. Alfalfa creates a low potential for nitrate leaching.

    b. Quality or quantity of crop requires high N input and frequent irrigation to ensure rapid vegetative and fruiting growth.

    c. Crop gives a high dollar return per acre and N costs are small compared to total costs.

    d. Crop does not suffer reduced yield or reduced quality when more than adequate amounts of N are applied.

2. Soils with a high potential for nitrate leaching.

    a. High infiltration rates.

    b. Low denitrification potential - usually sandy soils.

    c. No layers restricting water movement.

Pesticides

Pesticide mobility and persistence determine the pollution potential of a pesticide. Mobility refers to its ease of movement in a soil; persistence refers to the life of a pesticide. Both mobility and persistence depend on a complex interaction of volatilization, chemical transformations, adsorption to soil particles, solubility, and water flow.

Persistence is described by the half-life (time required for half of the pesticide to be degraded). Mobility is described by the partition coefficient (ratio of pesticide concentration bound to soil particles and concentration in soil water). The smaller the partition coefficient, the higher the leaching hazard of the pesticide. Table 4 lists half-lifes and partition coefficients for some pesticides.

Because of the complexity of pesticide movement in soil, a screening model was developed by the University of California, Riverside to assess the pollution potential of pesticides. Scenarios considered were a low pollution potential (fine-textured soil, high organic carbon, high soil water content, deep zone of biological activity) and a high pollution potential (coarse-textured soil, low organic carbon, low soil water content, shallow zone of biological activity). Results are given in Table 5 and show that only EDB presents a pollution hazard under low-pollution potentials (which would occur under a clay loam soil). For the high-pollution potential (which would occur under a sandy soil), most of the pesticides associated with groundwater contamination are a hazard.

Mitigating Adverse Effects Through Improved Irrigation

Pollution of groundwater can be reduced by reducing deep percolation from irrigated land. Keys to reducing deep percolation are increasing the uniformity of the applied water and reducing the average depth applied. Both of these keys are described by the performance characteristics of distribution uniformity (DU) and irrigation efficiency. The DU is a measure of how uniformly water is applied throughout a field; irrigation efficiency is the amount of water beneficially used divided by the average amount applied. The higher the DU, the higher the potential irrigation efficiency.

There are three basic irrigation methods used in California: Surface irrigation (most commonly furrows), sprinklers, and low volume irrigation such as drip or trickle. There are many variations of these basic methods, and some hybridization between the methods. Pressurized systems are, in general, capable of higher uniformities and higher potential irrigation efficiencies. However, field experience has shown that practical maximum potential uniformities and efficiencies are similar for all irrigation methods.

Measures for improving the uniformity and irrigation efficiency of applied water include the following:

1. Upgrade surface irrigation.

    a. Reduce the run or field length. This is the most effective measure provided the set time is also reduced by at least one half. This measure can reduce deep percolation by 50 to 80%.

    b. Increase the border or furrow flow rate. This may be most effective for border or basin irrigation. Its effectiveness for furrow systems is questionable.

    c. Convert to surge irrigation. This method, which cycles water on and off, can reduce deep percolation by 30 to 40%.

    d. Use furrow torpedoes. Torpedoes are small weighted steel cylinders dragged in the furrow. They smooth the soil surface, and may reduce the soil surface infiltration rate.

e. Improve slope uniformity.

f. Convert to level basin irrigation, where appropriate.

2. Convert to sprinkler irrigation such as periodic move systems in areas having high soil infiltration rates. Periodic move systems have poor uniformity during windy conditions. This problem can be avoided by irrigating only during low-wind periods (night-time), if possible.

3. Convert to linear-move machines (sprinklers or Low Energy, Precision Application (LEPA) systems) or low volume irrigation.

4. Automate the irrigation system. System automation provides the operational flexibility necessary to achieve improvements in uniformity and efficiency which may not be attainable under manual control.

In some areas, surface runoff is a problem, primarily because of its sediment load. Nitrogen injected into the irrigation water of surface irrigated fields may also contaminate receiving waters. Sediment loading in surface runoff can be reduced by:

1. Reduce the stream size.

2. Use cutback irrigation, where feasible.

3. Change some cultivation practices.

4. Change direction of irrigation to one of a lower slope.

5. Use a tailwater recovery system.

6. Use vegetative buffer strips or sediment retention ponds.

Opportunities for improved irrigation water management depend not only on the type of irrigation system, but also on the existing level of management. Farmers with high levels of management may experience little improvement in crop yield and little reduction in applied water and drainage output when they change irrigation methods to reduce drainage. Thus, conversions from surface irrigation to pressurized irrigation may be of little benefit. However, substantial benefits may be realized where existing management is poor.

Better management through improved irrigation scheduling can also reduce drainage volumes if better timing decreases the number of irrigations or if better estimates of soil moisture depletions decrease the average depth applied. Irrigation scheduling where high water tables exist is complicated by the crop's use of the shallow ground water. Up to 60% of the crop's water use may come from the shallow ground water if the roots are in contact with the water table. The amount of applied water must be adjusted to account for this contribution to prevent excessive drainage volumes in problem areas.

Improved Chemical Management

Nitrate

Nitrate leaching can be reduced by improved fertilizer management. Factors involved are amount and timing of application, type of fertilizer used, and cropping patterns.

Estimating the amount to apply to minimize nitrate leaching can be difficult. It depends on the crop's needs, on the residual nitrogen in the soil, and on nitrate in the irrigation water. Soil sampling can provide an estimate on residual levels of nitrate, but the large spatial variability of soil nitrogen makes precise estimates difficult to obtain. Even then, at best, about 70% of the applied nitrogen is used by the crop.

Fertilizer should be applied to provide the needed nitrogen when required by the crop. Timing depends on the type of material used and on the crop. Lettuce, for example, uses 70% to 80% of its nitrogen during the 30 days before harvest.

The application method can affect nitrogen utilization and nitrate leaching. A common method is to broadcast the fertilizer. This method is indiscriminate regarding the growth stages of the plant roots, and can result in nitrate leaching particularly during the early stages of plant growth. Banding involves placing a concentrated amount of fertilizer in the soil at a depth conducive to seedling access. For furrow irrigation, banded fertilizer placed in the furrow bed at a shallow depth can minimize leaching. At shallow depths, water and fertilizer move laterally up into the beds. Banding in the furrow bottom will cause excessive leaching of nitrate.

Plants can also absorb nitrogen through their leaves and stems. Thus, nitrogen can be applied by foliar applications, although the amount applied per application may only be 10 to 25% of the total nitrogen requirement. Foliar applications on citrus have been found to have a much lower nitrate-pollution potential than soil-applied nitrogen. A combined approach of applying nitrogen to the soil at a low rate followed by foliar applications as a supplement can be practiced in some cases. The pollution potential of this approach would be lower than for an all soil-applied approach.

Commonly used sources of nitrogen are ammonium nitrate solution and urea-ammonium. Urea is converted to ammonium in a few days, after which it adsorbs to soil particles and is not readily leached. Nitrification inhibitors slow the conversion of ammonium to nitrate, thus reducing the potential of nitrate leaching. However, only one such material is registered for use in California. One problem with slow-release fertilizers is that the rate of release of nitrate may not match the plant's requirement.

Pesticides

Pesticide contamination of both ground water and surface water can be reduced through improved management of pesticides. However, guidelines for improved management practices appear to be sketchy. Recommendations found in the literature are as follows:

1. Apply recommended amounts of the pesticide, follow label instructions, and use only registered pesticides.

2. Select pesticides with minimal potential to reduce water quality. Factors to be considered include pesticide needs, pesticide properties (partition coefficient, rate of degradation, aquatic toxicity), soil properties, and management practices. Research in Florida has identified some selection criteria based on potentials for polluting groundwater or surface water. Considerations are in Table 6.

3. Consider the timing of application of a pesticide with the timing of the irrigation. A study in the Imperial Valley recommends that the period between pesticide application and irrigation be extended as much as possible to prevent pesticide contamination of surface runoff. A similar recommendation should apply where groundwater contamination could occur.

4. Consider the placement of the pesticide with respect to water flow. Some pesticides such as nematacides might be placed in the soil such that contamination of both surface runoff and groundwater might be minimized. A study in Kern County revealed no aldicarb in surface runoff where the material was placed 8 inches deep in a narrow band in the center of 8-12 inch beds. A shallow placement of these materials could also reduce pesticide leaching in a manner similar to placement as it affects nitrate leaching (discussed earlier).

5. Consider other possible practices such as crop rotation, resistant crop varieties, alternative pesticides and methods of application.

6. Consider applying integrated pest management practices, where possible. Handbooks developed by the University of California offer guidelines for implementing integrated pest management practices for some crops grown in California.

Integrated pest management (IPM) is the planned integration of a range of techniques to minimize pesticide effects on the environment. IPM has had some successes. Development of presence-absence sampling techniques for mites and aphids in crops (cotton, almonds, brussels sprouts) is reducing the requirement for pesticide applications as pest control advisors adopt the new methods. Changing rice herbicide applications and water management practices has reduced both herbicide requirements and contamination of surface runoff. Selective leaf pruning in grapes contributes to the elimination of fungicide treatment for Botrytis bunch rot while improving the wine quality of grapes.

IPM can also involve the interaction of irrigation (amount, timing, and method of irrigation) and pest/herbicide control. One experiment found that buried drip irrigation reduced the need to apply herbicides for tomatoes.

However, because of the complexity of cropping systems and the interactions between pest, host, potential pest enemies, and the environment, much is yet to be done. Most IPM information involves the management of insect pests; less information exists on nematodes and weed management. Of the six currently registered pesticides recognized as groundwater contaminants, only one, aldicarb, is an insecticide.

Water Treatment

Both short-term and long-term mitigation measures may require treatment of water used for municipal purposes for several reasons. First, uncertainty exists in the attainable reduction of contaminants to ground water from improved management of irrigation water and chemicals. Second, even if no more contaminants were leached below the root zone, considerable time will pass before contaminated water is flushed out of the system.

Several strategies for treating water exist. Where central treatment facilities exist, treatment for nitrate and pesticide removal might occur at that facility. Treatment also might occur at the well head or at a point-of-entry, e.g., the point-of-entry into a home. Some treatment methods include:

1. Reverse osmosis - Contaminated water is forced under pressure through a semi-permeable membrane which excludes large molecules. The effectiveness of reverse osmosis (RO) is dependent on pressure, membrane material, and level of pollutant. Adsorption of pesticides on the membrane is a primary factor in reducing contamination. In addition, disposal of the waste brine is necessary. Recovery can be as low as 40% of the original volume.

2. Distillation - Contaminated water is converted to a vapor phase, and then condensed back to a liquid phase. This process is effective in removal of inorganic contaminants, such as soluble salts, since these materials do not travel with the evaporated water. Distillation may not be as effective with volatile organic compounds which can travel with the evaporated water. Proper disposal of brine or salt residue is required.

3. Ion exchange - Ions causing contamination are exchanged for other ions. This method may need to be combined with another to be effective.

4. Granular activated carbon (GAC) adsorption - Contaminated water is passed through a GAC filter that adsorbs the contaminants. GAC units require periodic replacement of filter media and proper disposal of spent carbon.

5. Other methods - These include ultraviolet oxidation, electrodialysis, precipitation and co-precipitation, activated alumina and air stripping. Some of these methods are recent developments and little is documented about them.

MITIGATING DRAINAGE PROBLEMS ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY

Large areas on the west side of the San Joaquin Valley are affected by subsurface drainage waters with potentially adverse economic and environmental effects. Rising water tables have encroached into crop root zone, and have caused high levels of soil salinity. Dissolved mineral salts in the subsurface waters have been concentrated through evaporation and plant transpiration. The drainage waters have been implicated in environmental problems such as toxicosis of wildfowl at nesting and feeding sites in the region as well as increased pollution of the San Joaquin River.

Viable measures for in-valley drainage management are being sought to determine the best management practices. These measures can be broadly categorized as source control, treatment/removal, disposal, or institutional and jurisdictional in approach. Discussions on these methods as well as two case studies are presented.

Source Control

Since drainage water comes from irrigation water applied to land within and upslope of the problem areas, drainage reduction through improved irrigation management should be an integral part of any drainage water management program. Drainage reduction can be accomplished by improved irrigation scheduling, improved irrigation systems, and drainage water reuse.

Furrow and border irrigation are commonly used along the west side of the San Joaquin Valley. Methods of upgrading these irrigation systems include reducing field length and set time, increasing flow rate, converting to surge irrigation, converting to level basin irrigation, furrow compaction, and improving slope uniformity. If several methods are combined, considerable drainage reduction, up to 80%, might be obtained.

Other options are using hand-move sprinklers, linear-move sprinkler systems, LEPA systems, and drip irrigation. Hand move sprinklers are commonly used along the west side, but design considerations limit their uniformity potential, particularly under windy conditions. Drip irrigation is capable of precise application of water and chemicals but has high capital costs and has high maintenance/labor costs. A high degree of grower awareness is required for these systems to operate at their potential.

Substantial amounts of saline water can be used for irrigation of salt-tolerant crops with little yield reduction. Low-salinity water is used for the remaining irrigations. A constraint on irrigating with drainage water is the concentration of toxic elements in the water. Recent studies have shown some crops such as melons and vegetables may accumulate selenium in the plant tissues. Another constraint would be foliar damage by concentrated salts from sprinkler irrigation with drainage water.

Another method of using drainage water for crop production is water table management. This involves controlling the water table depth to encourage maximum crop use of the shallow ground water, which reduces the irrigation requirement.

Drainage reduction, as proposed here, would result in less irrigation water percolating through the root zone, and an increased use of saline water for crop production. This would increase the potential for excessive salt accumulation in the root zone. Thus, a salt balance favorable for profitable crop production must be maintained by leaching or flushing salts from the root zone.

The question of how much water is needed for leaching needs to be addressed. Where the irrigation water is assumed to be the salt source, the leaching requirement depends on irrigation and drainage water salinity and on the crop yield. Thus, for the low-salinity irrigation water used along the west side of the San Joaquin Valley, the leaching requirement for no yield reduction would be a few percent of the applied water, and thus substantial decreases in the volume of subsurface drainage could occur without any salinity effects. However, in high water table areas, salt accumulation in the root zone comes primarily from salt transport by upward-flowing saline ground water. Thus, the leaching requirement for high water table areas would be higher than for other areas.

Successful leaching requires good drainage, and thus some method of drainage water treatment or disposal is needed. Presently, evaporation ponds, either on-farm or regional, offer a short-term disposal method.

Treatment/Removal

The second category is treatment of drainage waters and removal of selected constituents. Treatment technologies may be broadly classified as biological, desalination, physicochemical, and adsorption. The most promising treatment options include the use of anaerobic bacteria, microalgal-bacteria, microbial volatilization, adsorption by iron filings, chemical reduction with ferrous hydroxide, and reverse osmosis.

Because these are largely unproven technologies, none of these options has received wide-spread acceptance for drainage water management. Other contributing factors include cost constraints, uncertainty in the level of treatment required to meet water quality objectives, and uncertainty concerning the ultimate disposal of by-products. Some of these obstacles may be overcome through partial treatment in combination with other management options, and financing incentives to local agencies and private landowners.

The treatment processes under current research and development are summarized as follows:

1. Anaerobic Bacterial Selenium Reduction (Biosel Process) -- Selenium is reduced to an insoluble species, mostly colloidal selenium, during passage through a biological reactor. Microfiltration to remove insoluble selenium finishes the process. This process is also effective in removing many trace heavy metals often present in drainage water.

2. Biological Volatilization of Selenium -- Selenium volatilization occurs when microbes in pond waters methylate selenium and release it to the atmosphere as relatively non-toxic volatile dimethyl selenide.

3. Selenium Removal by Iron Filings (Harza Process) -- This process consists of beds of iron filings through which the drainage is filtered. Selenium appears to be removed predominately by chemical adsorption on iron oxyhydroxide surfaces formed on the filings. Effective removal of several heavy metals, including nickel, copper, lead, cadmium, and hexavalent chromium in addition to selenium also occurs.

4. Ferrous Hydroxide Reduction of Selenate -- Ferrous sulfate and lime are added to the drainage influent in a chemical reactor. The resulting ferrous hydroxide reduces selenate to selenite or elemental selenium. The reduced selenium species are adsorbed onto iron oxides and removed from the water by gravity.

5. Microalgal-Bacterial Selenium Reduction Process -- Selenium is assimilated by microalgae and the sludge resulting from a bacterial methane fermentation has been observed to be effective in reducing selenium to an insoluble form.

6. Reverse Osmosis (RO) -- Desalinization of drainage water by reverse osmosis has been considered. Appropriate pretreatment of the feed water is essential to avoid plugging of the RO membranes. Reduction of other trace metals to low levels would also occur.

7. Biological Volatilization of Selenium from Soils -- Volatilization of soil selenium by fungi is a naturally occurring process, especially in seleniferous soils.

Volatilization converts the selenium into gas which is dispersed into the atmosphere in a relatively non-toxic form, making this process attractive for reclamation of selenium-contaminated soils.

8. Plant Volatilization of Selenium -- Some plants, such as Atriplex (salt bush), barley and crucifers (mustard plant), are capable of methylating selenium like the microbes. They volatilize selenium gases through their leaves.

Disposal

The third general category is disposal of drainage waters. Some specific methods in this category include discharge into surface water bodies such as streams, lakes, oceans and closed basin wetlands, percolation into ground water basins, evaporation and solar ponds, and deepwell injection. Some of these options are under constraint because of potential adverse environmental impacts. Harvesting of salt deposits in ponds and salt by-products from treatment processes such as desalination has been examined but its potential is very limited due to impurities, limited market for reclaimed chemicals, and distance to the market.

Institutional/Jurisdictional

The final category of options is institutional and jurisdictional measures, including increases in water price or tiered water pricing, regulations on crop-specific amounts of water delivered to the farm, water marketing, imposition of drainage effluent fees for treatment and disposal, reallocation of water for nonagricultural uses, and land idling or retirement of the more severely impacted lands. The increased competition for water and growing awareness of the deleterious impacts of agricultural drainage on the environment are anticipated to result in changes in water and land use policies and regulations.

If higher-cost management options such as treatment, removal and disposal are required, the agricultural users may not be able to bear the entire cost and cost sharing policies may be required. When economical and equitable options have been exhausted, a change in land use may need to be considered.

Case Study 1 -- Agricultural Evaporation Ponds

Evaporation ponds are one means of drainage water disposal. Most of the 27 existing ponds are in the Tulare and Kern Subareas, with some as far north as the Grassland Subarea. Several ponds have been abandoned and others are inactive.

The hydrology of evaporation ponds consists of three inputs--drainage water influent from croplands, rainfall, and in some cases influent from perimeter drains intercepting pond seepage, and two outputs--evaporation and seepage, and change in storage of water in the pond. Drainage water in the evaporation ponds evaporates leaving behind precipitated salts and trace elements. Some decrease in the evaporation rate occurs as the salinity increases. The amount of dissolved mineral salts discharged into the 27 evaporation ponds is estimated to be greater than 0.8 million tons per year. The annual discharge of boron and selenium salts into the ponds is estimated to be 600 and 2.5 tons, respectively.

Evaporation ponds are not generally regarded as a viable long-term solution to the drainage problems in the San Joaquin Valley because of the concentration to toxic trace elements which are deleterious to the birds that use them. These adverse environmental effects have caused a few ponds to be judged functionally hazardous. The potential for long-term operation of these ponds is under review by various state and federal agencies. Currently, pond operators are assessing their ability to manage their ponds to minimize environmental problems. The desire is to avoid any repetition of the conditions which led to wildfowl toxicosis at Kesterson Reservoir in 1983.

Case Study 2 -- Agroforestry

The second case study involves using agroforestry techniques to reduce volumes of drainage waters by reuse. Agroforestry is propagation of salt-tolerant silvicultural crops using drainage water. This treatment method may produce income from the silvicultural crop while at the same time disposing of the drainage water. The method has been shown to reduce the amount of area for drainage water disposal in ponds by up to 70%.

As of 1988, agroforestry was being demonstrated at 22 sites for a total of 198 acres along the west side of the San Joaquin Valley. The principal site is located on Murrieta Farms near Mendota. It is a 28-acre plot planted principally to Red River Gum (Eucalyptus camaldulensis). A few rows of Casuarina (C. glauca and C. cunninghamiana), Elderica Pine (Pinus elderica), and Rose Gum (Eucalyptus grandis) are also planted. Selenium-accumulating saltbush (Atriplex sp.) was planted on 5 acres to study its ability to bio-filter the selenium. Other sites are operated from north of Mendota to as far south as Buttonwillow. At these sites, the above species, as well tamarisk, poplar, and mesquite, are under trial for their ability to produce biomass under saline conditions to test the feasibility of commercial production.

At Murrieta Farms, information is being collected on hardiness of the trees, economics of production and marketing, and wildlife use of the plantations. Monitoring of soil, water, and plant tissues has been undertaken to determine the potential effects of drainage water on the ecosystem. Saltbush is being assessed for its biological efficacy at removing selenium from the drainage waters and its ability to be made into a livestock food additive for animals in selenium deficient regions. However, it was discovered that Atriplex attracts leaf hoppers, an insect pest that may impact neighboring sugar beet fields.

Research on mitigation of the drainage problem by this method has been largely positive, though continued studies for its long-term efficacy are required.

SUMMARY

Nitrate and Pesticides

Nitrate and pesticide leaching into the groundwater can be reduced by improved management of irrigation water and chemicals. Improved irrigation water management includes upgrading existing surface irrigation systems, converting to pressurized systems (where appropriate), and improved irrigation scheduling. Improved chemical management includes applying the right type of chemical in the right amounts at the right time. While high potentials for reducing chemical leaching may exist, the practical reductions attainable, and their impact on groundwater quality are uncertain. For example, drip irrigation has the potential for distribution uniformities greater than 90%, however, attainable DU's are probably between 80 to 90%. The potential for upgrading existing surface irrigation systems in areas with nitrate and pesticide contamination is uncertain. Further investigations are needed to better define the potential for improvement.

Improved chemical management requires better estimates of amounts needed and better timing. Site specific information such as effect of soil type on water management, nitrogen availability, and pesticide movement may restrict the potential for fine-tuning chemical management.

A major obstacle is lack of information and skills for improving water and chemical management. Improvements involve a complex interaction of soils, plants, water, and chemicals. While qualitative information on improvements is available, quantitative information for the site-specific conditions of a given grower is needed. Obtaining this information can be difficult because of soil variability, temporal variability of water and chemicals, uncertainty of the response of chemicals in a soil environment and lack of simple methods of measurement. Current efforts at developing and assessing simple computer-based methods of evaluating surface irrigation will help overcome this obstacle.

Another obstacle to improved management of both water and chemicals is economics. Many of the crops grown in the areas with substantial groundwater contamination have high cash value. The cost of water, nitrogen, and pesticide inputs may be relatively small compared to the cash value of the crop. Thus, there is little economic incentive for growers to improve practices to reducing leaching of chemicals. Implementation of improvements may cost more than any reduction of costs due to decreased water and chemical applications, thus reducing profits. Other impediments to improved irrigation and chemical management include institutional constraints such as inflexible water deliveries from irrigation districts.

The best strategy for mitigating adverse impacts may depend on the seriousness of the impact and on the likelihood of reducing adverse impacts by various mitigating measures. While growers should be expected to manage irrigation water and chemicals at attainable potentials, the attainable potential and its effect on groundwater pollution is uncertain at this time. Further investigations, both modeling and field monitoring, are needed to assess the potential effect of various degrees of improved irrigation water and chemical management and the time-frames involved. Such a study is in progress for the Salinas Valley, conducted by the Department of Land, Air, and Water Resources, UC Davis and the Monterey County Flood Control and Water Conservation District. Meanwhile, where groundwater pollution from non-point sources presents a serious health problem, treatment of the water is needed for immediate mitigation of adverse effects. However, long-term mitigation will probably require a combination of water treatment and improved management of irrigation water and chemicals.

West Side of the San Joaquin Valley

Since irrigation is the cause of the west side drainage problem, improved irrigation water management should be an integral part of any solution. West side growers should be expected to make substantial reductions in subsurface drainage. However, in areas which will continue to be affected by saline high water tables, salinity control will limit the amount of reduction, and will require some form of drainage disposal.

Presently, in-valley disposal does not appear to be a long-term solution. Opportunities for treating drainage water for removal of toxic elements is uncertain at this time. Disposal options of evaporation ponds and deep-well injection appear to have unique problems which may restrict their implementation. Long-term sustainability of agriculture along the west side of the valley may require an ocean disposal method; however, this is a politically and environmentally sensitive issue, and this option will not likely be implemented in the near future, if at all.

APPENDIX

Tables 1-6

Table 1

AGRICULTURAL DRAINAGE WATER MANAGEMENT LOAN PROGRAM
LOAN FUND STATUS

	DEBIT	BALANCE
Total Authorization		$75,000,000
Administration Allowance	$3,750,000	
Total Available for Loans		$71,250,000
Funds Disbursed for Approved Projects		
Santa Ana Watershed Project Authority I	$15,051,000	
Panoche Drainage District I	$100,000	
Reclamation District No. 999	$500,000	
Gustine Drainage District	$100,000	
United Water Conservation Dist.	$75,000	
Buena Vista Water Storage District	$100,000	
Subtotal	$15,926,000	
Funds Available for Remaining Projects		$55,324,000
Funds Committed for Approved Projects		
Westlands Water District I	$1,498,000	
Lost Hills Water District I	$2,670,000	
City of Redlands	$2,750,000	
Imperial Irrigation District	$250,000	
OCWD, Irvine Desalter	$19,008,000	
City of Fresno, DBCP project	$4,008,000	
Panoche Drainage Dist., S.L. Drain project	$600,000	
Subtotal	$30,784,000	
Uncommitted Funds Available to Remaining Applicants		$24,540,000
Active Projects Competing for Remaining Funds in 1991		
Westlands Water Dist., Agroforestry project	$19,121,000	
SAWPA II, Chino Desalter	$15,200,000	
City of Sanger, DBCP project	$3,215,000	
City of Riverside, DBCP project	$14,400,000	
	$51,936,000	
Net Deficit[1]		($27,396,000)

[1] Does not include losses to Pooled Money Investment Account

Table 2

AGRICULTURAL DRAINAGE WATER MANAGEMENT LOAN PROGRAM 1990 PRIORITY LIST

Agency	Loan Amount $1000	Project Description	Status
City of Fresno	$4,008	Construction of well-head treatment facilities (13 mgd) for removal of DBCP	Preparing for Board approval in 1990
City of Sanger	$3,215	Construction of well-head treatment facilities (5 mgd) for removal of DBCP	Preparing for Board approval in 1991
Orange County Water District	$19,008	Construction of salinity and nitrate removal facilities (6.2 mgd) for contaminated ground water in the Irvine area	Preparing for Board approval in 1990
Westlands Water District	$19,121	600-acre agroforestry project	Preparing for Board approval in 1991
City of Riverside	$14,400	Construction of well-head treatment facilities (6 mgd) for removal of DBCP	Preparing for Board approval in 1991
Panoche Drainage District III	$2,000	Construction of a drainage water by-pass around the Grasslands using the San Luis Drain	Preparing for Board approval in 1991
Santa Ana Watershed Project Authority II	$15,200	Construction of salinity and nitrate removal facility (5.3 mgd) for contaminated ground water in the lower Chino ground water basin	Preparing for Board approval in 1991
Panoche Drainage District II	$500	Construction of an expanded selenium removal facility using iron filings	Inactive
Broadview Water District	$5,000	Construction of a 3.9 mgd selenium removal or deep well injection facility	Inactive
Charleston Drainage District	$1,000	Construction of a 0.9 mgd selenium removal or deep well injection facility	Inactive
Pacheco Water District	$2,000	Construction of a 1.9 mgd selenium removal or deep well injection facility	Inactive
Westlands Water District	$1,980	Construction of a prototype biological treatment facility for removal of selenium	Inactive
Westlands Water District II	$16,522	Construction of an expanded deepwell injection facility (9 mgd)	Inactive
Lost Hills Water District II	$3,049	Construction of an expanded evaporation pond system	Inactive
Dudley Ridge Water District - South	$900	Construction of a drainage and evaporation pond system (0.6 mgd)	Inactive
Dudley Ridge Water District - North	$1,128	Construction of a drainage and evaporation pond system (1.25 mgd)	Inactive

Table 3

GUIDELINES OR CRITERIA FOR JUDGING THE RELATIVE SENSITIVITY OF AN AREA TO LEACHING OF NO_3 FROM IRRIGATED LANDS

Criteria or Guidelines

Factor	Low Sensitivity I	Medium Sensitivity II	High Sensitivity III
Receiving water	Not a source requiring low NO_3 concentrations. Already has such high NO_3 load that more will do no damage. High dilution of drainage waters. Irrigated agriculture is an insignificant source of NO_3	Intermediate situations.	Multiple uses, some requiring low NO_3 concentrations. Low dilution of drainage waters. No alternate supplies. Economic impact of NO_3 leaching is high. Irrigated agriculture is a significant source of NO_3.
Soils	Clayey soils and soils having layers that restrict water flow limit drainage volume and promote denitrification.	Loamy soils, intermediate in water flow characteristics.	Sandy soils having no layers that restrict water flow. Well-aggregated soils that have high water flow characteristics.
Crops	Require low N inputs and/or have high N use efficiencies. Hay crops including legumes, grains, sugarbeets, grapes.	Good mixture of crops requiring high N inputs with low efficiency of use with crops that are efficient and that require low N inputs.	Vegetable and fruit crops of low N use efficiency requiring high N inputs. No or low acreage of efficient crops in the area.
Irrigation	Efficient systems and management that allows low drainage volumes. Typically well-managed sprinkler systems with controls on quantity of water used or drip systems.	Carefully managed surface irrigation systems where low drainage volume is expected. Mixture of efficient and inefficient systems.	Inefficient systems that promote large drainage volumes. Typically surface flow systems with long irrigation runs and large amounts of water are used.
Climate	Low rainfall that creates no leaching hazard.	Infrequent rains that occasionally promote leaching.	Heavy winter rains concentrated in a short period. Temperatures are sufficiently high for nitrification and winter crops are grown.

Table 4

GROUPING OF SELECTED PESTICIDES BY PERSISTENCE AND SORPTION IN SOILS

Common Name	Trade Name(s)	Partition Coefficient	$T_{1/2}$ (days)
NON-PERSISTENT (half-life 30 days or less)			
dalapon	Basfapon, Dowpon	1	30
dicamba	Banvel	2	14
chloramben	Amiben	15	15
metalaxyl	Ridomil	16	21
aldicarb	Temik	20	30
oxamyl	Vydate	25	4
propham	Ban-Hoe, Chem-Hoe	60	10
2,4,5-T	Dacamine 4T, Trioxone	80	24
captan	Orthocide, Captanex	100	3
fluometuron	Cotoran, Lanex	100	11
alachlor	Alanex	170	15
cyanazine	Bladex	190	14
carbaryl	Sevin	200	10
iprodione	Rovral	1,000	14
malathion	Cythion	1,800	1
methyl parathion	Penncap-M, Metacide	5,100	5
chlorpyrifos	Lorsban, Dursban	6,070	30
parathion	Thiophos, Bladan	7,161	14
fluvalinate	Mavrik, Spur	100,000	30
MODERATELY-PERSISTENT (half-life greater than 30 but less than 100 days)			
picloram	Tordon	16	90
chlorimuron-ethyl	Classic	20	40
carbofuran	Furadan, Curaterr	22	50
bromacil	Hyvar, Bromax	32	60
diphenamid	Enide, Rideon	67	32
ethoprop	Mocap	70	50
fensulfothion	Dasanit	89	33
atrazine	Attrex	100	60
simazine	Princep	138	75
dichlobenil	Casoron	224	60
linuron	Lorox, Aflon	370	60
ametryne	Evik	388	60
diuron	Karmex	480	90
diazinon	Basudin, Spectracide	500	40
prometryn	Caparol, Primatol Q	500	60
fonofos	Dyfonate	532	45
chlorbromuron	Maloran	996	45
azinphos-methyl	Guthion	1,000	40
cacodylic acid	Bolate, Bolls-Eye	1,000	50
chlorpropham	Beet-Kleen, Furloe	1,150	35

Table 4 (continued)

GROUPING OF SELECTED PESTICIDES BY PERSISTENCE AND SORPTION IN SOILS

Common Name	Trade Name(s)	Partition Coefficient	$T_{1/2}$ (days)
	MODERATELY-PERSISTENT (half-life greater than 30 but less than 100 days)		
phorate	Thimet	2,000	90
ethalfluralin	Solanan	4,000	60
chloroxuron	Tenoran, Norex	4,343	60
fenvalerate	Extrin, Sumitox	5,300	35
esfenvalerate	Asana	5,300	35
trifluralin	Treflan	7,000	60
glyphosate	Roundup	24,000	47
	PERSISTENT (half-life greater than 100 days)		
fomesafen	Flex	50	180
terbacil	Sinbar	55	120
metsulfuron-methyl	Ally, Escort	61	120
propazine	Milogard, Primatol P	154	135
benomyl	Benlate	190	240
monolinuron	Aresin, Afesin	284	321
prometon	Pramitol	300	120
isofenphos	Oftanol	408	150
fluridone	Sonar	450	360
lindane	Isotox	1,100	400
cyhexatin	Plictran	1,380	180
procymidone	Sumilex	1,650	120
chloroneb	Terraneb	1,653	180
endosulfan	Thiodan, Endosan	2,040	120
ethion	Ethion	8,890	350
metolachlor	Bicep	85,000	120

Table 5

MASS OF PESTICIDE REMAINING (%) AND TRAVEL TIME TO 3 METERS

Low Pollution Potential			High Pollution Potential		
Pesticide	Remaining (%)	Time (Yr)	Pesticide	Remaining (%)	Time (Yr)
Captan	0.00	10.1	Chlorphyrifoa	0.00	137.2
Carbaryl	0.00	52.5	DDT	0.00	5400.1
Chlordane	0.00	8210.2	Disulfoton	0.00	36.6
Chlorphyrifoe	0.00	1314.0	Malathion	0.00	41.0
DDT	0.00	51837.3	Methyl parathion	0.00	115.9
Diazinon	0.00	21.4	Parathion	0.00	248.1
Dieldrin	0.00	2594.7	Pentachlorophenol	0.00	322.1
Disulfoton	0.00	343.6	Propachlor	0.00	10.0
EPTC	0.00	63.5	Trifluralin	0.00	164.8
Fenamiphos	0.00	39.9	Toxaphene	0.00	478.1
Heptachlor	0.00	5186.5	Chlorthaldimethyl	0.00	90.6
Lindane	0.00	288.3	Triallate	0.00	81.6
Linuron	0.00	189.4	Chlorothalonil	0.00	31.6
Malathion	0.00	390.9	Captan	0.00	1.3
Methyl parathion	0.00	1104.5	Fenamiphoe	0.00	4.4
Napropamide	0.00	67.8	Cyanazine	0.00	4.4
Oxamyl	0.00	4.3	Dieldrin	0.00	270.6
Parathion	0.00	2378.8	Heptachlor	0.00	540.5
Pentachlorophanol	0.00	145.5	Linuron	0.00	20.0
Prometryn	0.00	3089.3	Carbaryl	0.00	5.8
Phorate	0.00	134.7	Chlordane	0.00	855.5
Propachlor	0.00	93.7	Prometryn	0.00	14.3
Triallate	0.00	780.5	EPTC	0.00	6.9
Trifluralin	0.00	1579.6	Phorate	0.00	15.4
Alachlor	0.00	35.4	Alachlor	0.00	3.87
2,4-D	0.00	7.8	2,4-D	0.00	1.0
2,4,5-T	0.00	20.3	Dichloropropene	0.01	2.1
Chlorthal dimethyl	0.00	866.9	Oxamyl	0.02	0.7
Metolachlor	0.00	42.1	Lindane	0.04	29.8
Chlorothalonil	0.00	301.0	Metolachlor	0.04	4.7
Dichloropropane	0.00	17.7	Napropamide	0.06	7.8
Toxaphene	0.00	4538.5	Diazinon	0.40	2.5
Atrazine	0.00	87.6	2,4,5-T	0.60	2.4
Cyanazine	0.00	39.3	Ethoprophoe	0.97	3.3
Ethoprophoa	0.00	28.9	Atrazine	0.99	4.2
Simazine	0.00	33.2	Simazine	2.98	3.7
Fonofoa	0.00	17.7	Dicamba	3.84	0.6
Diuron	0.00	35.1	Fonofoa	8.25	2.1
Monuron	0.00	41.9	Metribuzin	11.47	1.1
Dicamba	0.00	3.5	Carbofuran	11.52	1.2
Terbacil	0.00	11.9	Terbacil	11.76	1.5
Carbofuran	0.00	9.0	Propylenedichloride	13.49	1.6
Propylene dichloride	0.00	12.3	Monuran	13.96	4.6
Metribuzin	0.00	8.2	Diruon	14.08	9.1
Aldicarb	0.00	10.8	Aldicarb	24.27	1.4
Picloram	0.00	18.4	Picloram	30.70	1.7
DBCP	0.02	18.1	DBCP	50.70	2.2
Bromacil	0.26	18.6	Bromacil	64.08	2.2
EDB	68.02	12.5	EDB	96.98	1.6

Table 6

CONSIDERATION OF PERSISTENCE AND SORPTION OF A PESTICIDE IN DETERMINING ITS POTENTIAL TO CONTAMINATE GROUNDWATER AND SURFACE WATER.

Persistence	Sorption	Potential Impact	
		Ground water	Surface water
Nonpersistent	Low-Moderate	Low	Low
Nonpersistent	Moderate-High	Low	Moderate
Moderately persistent	Moderate-High	Moderate	Moderate
Moderately persistent	Low-Moderate	High	High
Persistent	Moderate-High	Moderate	High
Moderately persistent & persistent	Low-High	Site-specific conditions determine groundwater or surface water impacts	