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RECLAMATION DISTRICT NO. 1500

RESOURCE STUDY

SUTTER COUNTY, CALIFORNIA

ATTACHMENT 4

NATURAL RESOURCES STUDY

FOR

RECLAMATION DISTRICT 1500

AND

SUTTER MUTUAL WATER COMPANY

FEBRUARY 1996

Prepared by

USDA Natural Resources Conservation Service

USDA Forest Service

in cooperation with

Sutter County Resource Conservation District

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EXECUTIVE SUMMARY

Purpose and Objectives of Study

The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, was requested by the Sutter County Resource Conservation District, Sutter Mutual Water Company (Company), and Reclamation District 1500 (District) to study the resource issues and opportunities for resource enhancement within the District's boundaries in the Sutter Basin.

The District and Company are interested in and concerned with water conditions in their service area. While they are mandated to update their water management plan, they are also interested in the potential effects reduced water use may have on the environment and farmland. One example is that the drainage water from this area is currently discharged into the Sacramento River from the Karnak pumping plant and changes in water use or management made in the study area would impact the river. Currently, the irrigation water used in the summer helps dilute the saline drain water in the area. Improvements in water conservation may increase the salinity of the return discharges to the Sacramento River.

The Reclamation Reform Act and the Central Valley Project Improvement Act require that entities contracting for Federal water project supplies develop water conservation plans. These plans must examine existing water management practices, evaluate other water management strategies, and determine how to implement appropriate water conservation measures. The Bureau of Reclamation has identified 14 potential additional measures that should be evaluated for suitability in reaching water conservation goals. This report evaluates these measures with respect to conditions in the study area and summarizes the results for applicability and feasibility to the Sutter Basin.

Resource Features of Study Area

The study area is approximately 68,000 acres and is completely enclosed by three levee systems. The town of Robbins, 22 miles northwest of Sacramento, is the central business and residential center of the area.

The climate of the area is typical of a Mediterranean climate with hot, dry summers and cool, moist winters.

It has been suggested that during the Late Paleocene Period, an inland sea was trapped in the Sacramento Valley, leaving a mound of saline connate water underground. It is believed that this connate water, containing principally sodium and chloride, rises upwards through the Sutter Basin Fault under artesian pressure. Before the construction of the levees, the Sutter Basin was covered with water during most of the spring months, and in summer the land was swampy in places and covered with tules. Natural precipitation and flooding kept the salts in the soil leached. After levee construction proper irrigation and drainage have kept the salts under control.

The two major crops grown in the study area are rice and tomatoes, the latter in rotation with wheat, corn, safflower, and beans. Rice may be grown in rotation with crops such as wheat, safflower, beans, and melons though some growers grow rice seven to eight years in a row.

Water quality concerns in the area center on salinity. The water supply from the river is of excellent quality and averages 130 micromhos/cm electrical conductivity (EC). Water running off of fields flows into the drains where it picks up volume and salinity from the subsurface water seeping into the drains. The EC of the water at the main drain is typically ten-fold greater than that of the supply water before and after the irrigation season and five-fold greater during the irrigation season. The water used for crop irrigation apparently dilutes the salt concentration in the drain water. From 1987 to 1992 the EC of the main drain at Karnak varied from 380 to 780 micromhos/cm during the irrigation season. In the winter the EC ranged from 420 to 1,500 micromhos/cm.

While the conversion to agriculture has reduced riparian, prairie, and marsh habitat and the species associated with these habitats, other wildlife species have been favored by agricultural development. Species such as the western yellow-billed cuckoo, Swainson's hawk, bank swallow, wood duck, bald eagle, giant garter snake, western pond turtle, California tiger salamander, California red-legged frog, Chinook salmon, valley elderberry longhorn beetle, and the California hibiscus are only found at low levels and some are even listed as State or Federal threatened or endangered species. On the other hand, migratory waterfowl are doing very well in those areas where rice, wheat, barley, milo, corn, and beans are being grown. Grain provides good nesting habitat and the rice fields also provide good habitat throughout the summer and into the fall and, in some cases, through the winter. The ditches are good habitat for blue and channel catfish, carp, crayfish, and bullfrogs while the banks and levees are used by pheasants for nesting.

Water Resources Inventory

In the early 1900s levees were constructed as protection against overflow from flood waters and for navigation. Shortly after the levees were built, the irrigation and drainage systems for the basin were constructed.

Most of the irrigation water in the study area is pumped from the Sacramento River. A small number of wells are used and some drainwater reuse exists within the service area.

In 1990, 197,200 acre-feet of water were diverted from the river by the Company. The Company maintains and operates four pumping plants. In addition, the Company operates 8 booster pumps and one internal recirculation system with a total combined capacity of 290 cubic feet per second (cfs) per day.

The manner in which rice is irrigated is unique among all the crops in the basin. Rice has a higher evapotranspiration rate than other crops and needs to be in a fully saturated field. The rice fields raise the water table in the surrounding fields because the water table becomes the water surface of the rice field. If the water table approaches the root zone of the crop, the crop can obtain water without irrigation. Less water is applied to melons than the crop needs because the crop meets its water needs from the water table. An estimated seventy-one of the 136 growers of tomatoes, beans, and melons are able to apply less than the crop actually needs.

The average crop irrigation requirement for the period 1981 through 1990 was approximately 85,800 acre-feet per year. Dividing the average crop irrigation requirement for the period by the average irrigation delivery of 172,800 acre-feet yields a service area-wide average on-farm efficiency of approximately 50 percent. Up to 1991 average efficiencies ranged from 45 to 55 percent with open ditch systems having lower efficiencies than piped systems. Since then efficiencies have increased to 60 percent due to water reuse and other practices. An arbitrary target efficiency of 80 percent was set in this study for the evaluation of the proposed changes in water management discussed in this report. The high water table in the area consists of seepage from the river, subsurface interbasin inflow from the surrounding area, and rising connate water under artesian pressure. Due to its high salt content, the ground water is not used for irrigation except along the Sacramento River, where the salt content is much lower. One potential source for salt buildup in the ground water is the upward movement of deep lying connate water driven by freshwater under an artesian head.

The concentration of salts increases with depth below ground. Studies performed on the saline connate water in the area indicate total dissolved solids concentrations in the ground water ranging from 248 to 5,970 mg/l in wells drilled from 72 to 1,500 feet deep. Ten to 20 feet below the surface the EC ranges from 1,000 to 4,000 micromhos/cm while 100 to 300 feet below the surface the EC range increases from 8,000 to 13,000 micromhos/cm.

The salt-laden ground water seeps into the drain ditches and causes an increase in EC in the drains. The salt concentration in the main drain is typically much higher during the winter than during the irrigation season. The good quality irrigation water dilutes the salty ground and drain waters.

Water and Salt Budgets

To establish a water budget, the year 1993 was used. The rainfall record from the Tisdale pumping plant produced a precipitation estimate of 22.14 inches. Records indicate that 184,532 acre-feet of water were diverted from the Sacramento River by the Company. Other Bureau of Reclamation contractors diverted an additional 26,034 acre-feet. It was assumed that water to the area was used for evapotranspiration (Et), lost to deep percolation, or drained into the drainage network. The estimated Et for the basin in 1993 was 224,537 acre-feet. The discharge at the Karnak plant was 201,275 acre-feet. The amount of water pumped from the river and wells by rimland farmers was estimated by Et. Rimlands and rim water are the local terminology for non-Company areas.

There are more salts leaving the basin than entering the basin. One theory is that previously accumulated salts are coming out of the soil profile. The average estimated salt load in surface water inputs was 0.14 tons per acre-foot, and the estimated drain outflow was 1.07 tons per acre-foot, an 8.5-fold increase.

Connate and rim waters were estimated to contribute about 40 percent of drain water outflow and roughly 20 percent of the salt outflow. The salt budget implies that 58 percent of the salt load from this area to the Sacramento River is leached from the basin's soils.

Description and Analysis of Water Conservation Measures

The Reclamation Reform Act and the Central Valley Project Improvement Act require that entities contracting for Federal water project water supplies develop water conservation plans. These plans need to examine existing water management practices, evaluate other water management strategies, and determine how to implement appropriate water conservation measures. The 14 measures recommended by the Bureau of Reclamation should be evaluated based on applicability to the district, technical feasibility, financial feasibility, improved efficiency of water delivery and use, quantity of water to be saved, and environmental impacts. These suggested measures have a demonstrated record of effectiveness in reducing losses of, making more efficient use of, or otherwise conserving water. Due to its lack of legal expertise, NRCS did not evaluate the measures for their legality under state and federal law. The 14 measures are as follows:

1. Incentive Pricing: Implement an increasing tiered block water pricing structure, or other water pricing structure, that promotes the efficiency of water use.

In 1993 the Company separated charges into a flat maintenance charge of $13 per acre per year plus a charge of $8 per acre-foot for water purchased. This charge applies to 50,083 acres in the study area.

Generally, this measure is applicable to the District both technically and financially. While it was not possible to determine the actual impacts of tiered pricing in the Sutter Basin, an attempt was made to estimate the potential water savings. The present overall on-farm irrigation efficiency for the major row crops of tomatoes, melons, and beans exceeds 100 percent because part of the water requirement is met by the shallow water table. However, water use data indicates some water savings is possible on a portion of these croplands. With data available from 75 percent of the total growers in the area and a target efficiency of 80 percent, it was estimated that the potential amount of water saved is 2,700 acre-feet. Expanding this to the other 25 percent growers would produce a potential water savings of 3,600 acre-feet. This is less than two percent of the total water diverted in 1993. This irrigation efficiency increase is only possible on cropland. Rice acreage irrigation water use is a function of crop water use which is fixed and soil seepage which varies by soil type.

Negative impacts include the reduction of water available for reuse, the reduction of water discharged at Karnak and available downstream, and the potential increase in salinity in the drains as a result of less dilution effect.

2. On-Farm Program Incentives: Facilitate and/or provide financial incentives and assistance for on-farm water use efficiency improvements.

As estimated under the discussion on tiered water pricing, only 3,600 acre-feet would potentially be saved with this type of incentive measure. While this measure is applicable to the District and technically feasible, it applies mostly to the row crops. Rice is generally grown in closed systems or with tailwater return systems so only minimal improvements to irrigation efficiency could be made. Only 12,000 of the remaining row crop acres would need to be improved to reach the target efficiency of 80 percent. On-farm educational and technical assistance to achieve this goal would cost $12 per acre-foot while system improvements could cost in excess of $50 per acre. Potential negative impacts are the same as those listed for the incentive pricing measure.

3. Drought/Water Shortage Contingency Plan: Develop a drought/water shortage contingency plan for the district that outlines the policies and procedures for operation and allocation during water supply shortages.

The Company has a mechanism in place to deal with drought/water shortage situations. This measure is applicable to the area and technically and economically feasible. The quantity of water saved and any environmental impacts from this measure are unknown.

4. Water Transfers: Facilitate voluntary transfers that do not unreasonably affect the district, the environment, or third parties.

The Company is currently exploring water transfer opportunities and needs to further examine the potential impacts on the Company, the environment, and third parties. This measure is applicable to the District and is technically feasible. While there is the potential for landowners or the Company to receive supplemental income, the local economy may be negatively impacted by the resulting reduction in agricultural input needs and crop processing services. The environment may also be impacted from additional salt buildup due to reduced irrigation applications.

5. Conjunctive Use: Increase conjunctive use of surface and ground water within the district, begin working with appropriate entities to develop a ground water management plan.

The District currently performs a form of conjunctive use by manipulating the water level in the drainage ditches. Any further form of conjunctive use is not applicable in this area due to the high water table and saline conditions of the ground water. This measure is not technically feasible to the area for this reason because another area would need to be found in which to store water underground. It would be costly to build a system to transport the water to another district, pump the water from the ground, and then transport it to another area as needed.

6. Land Management: Facilitate alternative uses for lands with exceptionally high water duties, or whose irrigation contributes to significant problems (e.g. drainage that does not meet discharge standards).

Present land management practices, cultivation, and irrigation water management are done in a manner that minimizes problems that relate to water discharges which exceed standards. In the high salinity areas irrigation has actually helped to make the land more viable for agriculture.

This measure is applicable to the District and technically feasible. Financial feasibility is limited due to the lack of other income-producing uses for the land. Some water would be saved if land was taken out of production but there may be a corresponding salt buildup in the soils, leading to an overall decrease in suitable habitat for the current species found in the area.

7. Operational Practices and Procedures: Evaluate potential district operational policy and institutional changes that could allow more flexibility in water delivery and carryover storage.

The existing system is fairly flexible. Current Company policy states that irrigation water delivery to growers requires a 48-hour advance notice and a 12-hour advance notice for shut off. The current system is effectively an on-demand schedule. Present policy allows ditch tenders to shut gates where water is obviously being wasted.

While this measure is applicable to the District, it may not be technically feasible due to the time required to allow water from Shasta Dam to reach the area. There would be costs associated with hiring more personnel to be available for water delivery and shut-off. There would also be costs associated with the installation of additional water management equipment. This measure would create more flexibility in water delivery, though not necessarily an increase in water use efficiency. Landowners might be able to save additional water if they had more flexibility in water delivery and shut-off, but there would also be less water in the ditches and canals which would reduce water edge habitat.

8. Irrigation System Scheduling: Implement a program of distribution system scheduling based on area-wide crop demand modeling or advanced demand requirements.

The responsibility of ordering water belongs to the grower.

This measure is applicable to the District and is technically feasible. As mentioned previously, 3,600 acre-feet could be saved by increasing the least efficient growers' efficiency to 80 percent. The assumption is made that, if growers are informed how much water they are using in comparison to other growers, they may see how they can also reduce their own water use. Care must be taken not to reduce irrigation levels below the amount needed to manage the connate water and continue leaching the salts from the soil. Saline soil would affect existing habitats and land uses.

9. On-Farm Scheduling: Facilitate the delivery of crop water use and on-farm delivery information to district customers for on-farm irrigation scheduling.

The Company is already distributing information in the growers' bills. Typical water use for each crop and the distribution of water orders in the area so growers can compare their use to that of other growers are examples of the type of information being made available. The maximum amount of potential water savings is the same 3,600 acre-feet discussed previously. There would be some cost associated with hiring personnel to provide landowners with education, information, and technical assistance.

10. Pump Efficiency Evaluations: Coordinate the evaluation of district and private pumps with local utilities, evaluating both energy and water efficiency.

The Company currently supports PG&E's pump testing program. This measure is applicable to the District and technically feasible. Energy and water cost savings could be increased, but there would be some expense associated with equipment and personnel costs for monitoring. There would probably be a negligible effect on the environment and no actual water savings.

11. Distribution Control: Modify distribution facilities and controls to increase the flexibility of water deliveries.

Ditch riders are currently allowed to close or reduce delivery to customers who are spilling water from their fields. This measure may be applicable to the District but is not technically feasible. The need to order water two days in advance from Shasta Dam limits flexibility of delivery. There would be many costs involved with automating equipment and hiring additional personnel. With the two-day advance notice limitation, there would be no significant increase in water delivery efficiency. There would be no significant environmental changes with this measure.

12. Reuse Systems: Construct district operational spill reuse system.

The Company presently reuses up to 15,000 to 16,000 acre-feet per year with an additional 15,000 to 16,000 acre-feet used by growers who pump from the drainage system. These figures will vary each year. Some growers also operate individual on-farm reuse systems.

A basin-wide recirculation system would lift water from Bohannon Dam upstream to the main canal. The estimate for 1994 of water which could have been available for reuse is 24,655 acre-feet. The discharge to the Sacramento River at Karnak would have an average EC of 2,263 micromhos/cm for July and 2,215 micromhos/cm for August and would have been reduced in volume. Salt would be stored in the soil profile during the irrigation season. If this water were recirculated in the basin, a much higher winter EC would become typical.

If the installation and maintenance costs of a reuse system are distributed over the Company's service area of 50,083 acres and amortized for 25 years at eight percent interest, the annual per acre cost of installation and maintenance is $5.50. The power cost for lifting the water back to the main canal is about four times the cost for lifting the water from the Sacramento River.

This measure is applicable to the District and is technically feasible. The efficiency of water use or delivery would not significantly change. For evaluation purposes, assuming that 50 percent of water discharged into the Sacramento River is available for reuse, an additional 52,500 acre-feet could be incorporated into a reuse program during the irrigation season. These figures are based on a water year similar to the year 1993.

There is a strong potential for increasing the concentration of natural salts in the basin due to the connate ground water source and less fresh water for leaching. The reduced amount of drain water that continues to be returned to the Sacramento River may involve higher concentrations of salts. There will be a need to mix fresh water with the reuse water to maintain the District's recommended EC level of 750 micromhos/cm. Growers would need to closely monitor the quality of the water they are applying.

13. Distribution System Lining: Line distribution ditches or canals or convert to pipe.

Conversion to Lined Ditch

Two ditch lining options were considered: lining approximately 34.4 miles of the 167 miles of ditch and lining 5.0 miles of ditch. The ditch segments recommended for lining are those in which the soils allow excessive amounts of irrigation water to seep into the ground water. The amount of water lost to seepage would be reduced by 37,100 acre-feet per year for 34.4 miles of lining and 19,700 acre-feet per year for 5.0 miles of lining. The analysis shows that 97 percent of the seepage losses from the canal system is lost from 34.4 miles, or 21 percent, of the ditch system. Fifty-two percent of the water is lost from three percent, or 5.0 miles, of the system.

This measure is applicable to the area and is technically feasible for those segments with excessive seepage. Lining 34.4 miles of ditch would cost $12.8 million, while lining 5.0 miles would cost $2.3

million. The average annual costs, based on 10 years, would be $1,852,000, or $50 per acre-foot of water, for 34.4 miles of lining and $337,000, or $17 per acre-foot, for 5.0 miles of lining. This is about twice the current per acre-foot cost that the water user pays the Company.

There would be no significant improved efficiency of on-farm water use or delivery. The Company would have increased efficiency of water delivery. Lining would eliminate the same number of miles of water edge and open water habitat.

Conversion to Pipeline

Maintenance of a piped system would require replacement every 25 years. Estimated pipe maintenance costs are $1,500 per pipe mile. The estimated cost of 34.4 miles of a pipeline system is $75 million. The minimum average annual cost would be $9.5 million. The estimated cost per acre-foot would be $225 and could be much higher. The added cost would raise the annual fee for the assessed gross acres of 50,083 by about $190 per acre.

The Company could manage water delivery more easily and efficiently; however, there would still be a need to order water from Shasta Dam in advance. Drain water reuse in the basin would no longer be able to take place. Approximately 42,000 acre-feet of water would be saved with this measure.

Piping the ditches would eliminate 613 acres of open water habitat and 840 acres of water edge habitat. There is a strong potential of increasing the salt concentration in the basin with the decrease in the dilution effect of the seeped water into the connate water. The drain water returned to the Sacramento River may involve higher concentrations of salts.

14. Construction or Lining of Regulatory Reservoirs: Construct or line regulating reservoirs.

Currently, the Company's control of water delivery is limited. There is no Company regulating reservoir; however, the main canals have significant storage capacity and function as regulating reservoirs. Between 3,600 and 76,000 acre-feet of water could be stored to be used at a later time depending on the types of improvements made.

This measure is applicable to the area and is technically feasible. The Company would need to gain support of the growers and provide appropriate incentives to implement a significant modification to the way growers manage their farming operations. Growers would need to pay for the infrastructure and operation costs in terms of higher assessments. The Company would be faced with the purchase cost of land, cost associated with construction of the water-holding basin and associated infrastructure, and annual operation and maintenance expense.

Some agricultural land would need to be taken out of production for the construction of a basin. Some additional wetland habitat could be created with the development of a basin.

Table 7 summarizes these measures.

Opportunities and Considerations

For this study a resource inventory was performed and the information developed was used to assess the recommended Bureau of Reclamation water conservation measures. Bureau contractors such as Sutter Mutual Water Company are required to prepare a water conservation plan evaluating these measures.

The result of this assessment indicates that, while there is room for slight improvements, local growers, Sutter Mutual Water Company, and Reclamation District 1500 are efficiently utilizing the water resources available to them. Any dramatic modifications to the way water is managed in this basin requires further research and understanding of ground water fluctuations and the movement of the connate water.

A relatively small amount of water, 3,600 acre-feet or two percent of the District's total water diverted in 1993, could be saved with the implementation of suggested measures such as tiered pricing, on-farm incentives, or changes in irrigation or delivery scheduling. More water, up to 84,500 acre-feet, could be saved with measures such as reuse and lining or piping of ditches. These measures, however, may severely impact irrigation water quality and the ability to produce crops, may have negative environmental impacts, or may not actually save water. Water reuse to its highest level will potentially increase salinity in the soil and water to unmanageable levels. Water seeping from the ditches is not actually "lost"; rather, due to the high water table, most of the ground water seeps into the drain ditches and is discharged at Karnak. In fact, this water actually helps dilute the saline ground water, producing a higher quality water for discharge into the Sacramento River. The elimination of wildlife habitat would also be significant.

There are some opportunities for environmental enhancement. While present agricultural practices and the water distribution system are beneficial to many fish and wildlife species, there are practices which could offer further enhancement. The Company has become well informed about the installation of fish screens on pipes removing water from the Sacramento River and is ascertaining the best design and related costs of controlling fish at the pump inlet. Establishing nesting boxes or windbreaks near rice fields will help attract and maintain wood ducks. Planting fence rows, ditch banks, and row or field edges to native grasses with clovers provides cover for wildlife and can eventually out compete weeds, reducing the need to burn or spray.

It is recommended that the U.S. Geological Survey be consulted to formulate a plan to study the ground water and develop a three-dimensional isoconcentration map. A well management plan and a ground water model could be the product of this plan.

There are some limited opportunities for water conservation on 12,000 acres of row crops, excluding rice, in the study area. The amount of water saved would not exceed 3,600 acre-feet. Switching to sprinklers for early irrigations, eliminating one or two unnecessary irrigations, and shortening sets were preliminary suggestions developed from the use of the AGWATER computer model.

It was determined in this study that growers are not planning any significant changes in land or resource use in the foreseeable future. There is a stable and healthy farming economy with a stable crop pattern. Drastic cutbacks in water availability would most likely lead to an increase in soil salinity and impact crop productivity and have an adverse impact on wildlife habitats and populations.

SECTION I

INTRODUCTION

Background

The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, was requested by the Sutter County Resource Conservation District, Sutter Mutual Water Company (Company), and Reclamation District 1500 (District) to study the resource issues and opportunities for resource enhancement within the District's boundaries in the Sutter Basin.

Reclamation District 1500 is a Special District formed by a special act of the legislature in 1913, with a primary purpose of agricultural drainage, flood control, and levee maintenance.

The Sutter Mutual Water Company was incorporated in 1919 and has been continuously delivering irrigation water to lands for over 72 years.

Major Concerns and Opportunities

The District and Company are interested in and concerned with water conditions in their service area. They requested a study addressing water quality, water management and conservation, and excess drainage.

The District and Company wanted to evaluate their historic use of water and land use. While they are mandated to update their water management plan, they are also interested in the potential effects reduced water use may have on the environment and farmland. One example is that the drainage water from this area is currently discharged into the Sacramento River and changes in water use or management made in the study area would impact the Sacramento River. Currently, the irrigation water used in the summer helps dilute the saline drain water in the area. Improvements in water management may increase the salinity of the return discharges to the Sacramento River. The District also wanted to investigate resource enhancement opportunities for water and soil use and wildlife habitat.

Objectives

There are three identified objectives for this document:

1. Present an inventory and assessment of the present use of the area's water, soil, and environmental resources.

2. Discuss the enhancement opportunities for these resources.

3. Predict the potential impacts of significant changes in resource uses or allocations.

Ecosystem-Based Concepts

An ecosystem is a community of living things and their chemical and physical environment. A field can be considered an ecosystem, as can an entire farm or watershed. Changes in a small ecosystem may have impacts on a larger ecosystem. Ecosystem management considers the interaction of human and natural resources to reach a desired condition. Decisions are based on sustaining ecosystem health while providing social and economic benefits.

In an ecosystem such as the study area, knowledge of the interaction and characteristics of both the surface and ground waters are essential to the understanding of the dynamics of the area and for opportunities to be recognized. This is also true of the biological habitat found in the area. The rotation of crops creates a fluid, ever-changing ecosystem. Evaluating strictly on a field by field basis would not present the whole picture of the habitat values in the area.

Ecosystem-based resource planning fosters development of plans on a watershed basis and forms a complementary mechanism to apply management and conservation practices on the individual land units. In this document all of the measures and opportunities considered will be viewed using the ecosystem concept. It is recommended that this approach be used in the future as well.

Use of This Product

This final document will be used by the District and Company to develop a total water, land use, and wildlife management plan which addresses the efficient and beneficial uses of the existing and potentially available water, soil, and other natural resources in the area. This report will assist the District in making sound business and resource management decisions and in being proactive to identified problem areas instead of reactive.

SECTION II

STUDY AREA RESOURCES

Location and Size

The study area lies in the Sutter Basin, approximately 22 miles northwest of Sacramento and 100 miles northeast of San Francisco (see Location Map, Figure 1). The area encompasses approximately 68,000 acres and is completely enclosed by three levee systems totaling 55 miles. The town of Robbins is the central business and residential center of the area.

Generalizations can be made within the study area but three areas appear to have distinct characteristics (Figure 2). These areas are: (1) the silt loams paralleling the Sacramento River (rim area), (2) the area above the mounded connate ground water (connate area), and (3) the remainder of the study area. When needed, options will be considered separately for these distinct areas.

The rim area is the only portion of the study area that historically has incurred salt buildup in the A horizon of the mapped soils. Any water conservation or management practice must determine the extent of leaching required to prevent recurrence of salt build up. The effects of selected practices must be analyzed on a worst case scenario or by continuous simulation since climatic fluctuation effects are apt to be lost in an analysis of averages.

Drainage ditches intercept subsurface connate water in the connate area, causing drain water to test high in salts. Both the rim and connate areas are atypical of irrigation management in that they are adversely affected by salts in the rising ground water.

The remaining area is more typical of irrigation management and can be looked at in the conventional manner of best practices for applied irrigation water and drainage.

Agricultural History of Area

All swamp and overflow lands were given over by the United States to the State of California on the condition that they be reclaimed. These lands were then conveyed to private owners on the condition that the owners reclaim the lands. In 1913, Reclamation District 1500 was created under California law for the purpose of reclaiming lands within the Sutter Basin.

By 1919, levees and ample irrigation and drainage facilities were in place in the Sutter Basin. Before that time the Sutter Basin was covered with water during most of the spring months, and in summer the land was swampy in places and covered with tules. Natural precipitation and flooding kept the salts in the soil leached before this time. The only land cultivated was that in private ownership bordering the river.

The main crops grown in the 1920s were alfalfa, asparagus, barley, oats, wheat, rice, beans, sugar beets, grapes for juice, orchards, and garden/truck crops such as melons, potatoes, onions, cucumbers, and pumpkins. The orchards were mainly peaches, pears, prunes, and plums. Other miscellaneous crops included seed peas, corn, Sudan grass seed, and peppermint. There were also several dairies in the basin during this time. Most of the land was summer fallowed as part of rotational cropping sequences. Salt levels in the soil probably increased during this time. Other areas that were not farmed were used for grazing, primarily by sheep. Most crops harvested during the 1920s and 1930s were trucked, shipped by rail, or barged down the Sacramento River to markets. These cropping patterns stayed essentially the same until the early 1940s, which was the beginning of the U. S. involvement in World War II.

During and after World War II the cropping patterns started to change. Many vegetable crops produced reasonable yields, but the area proved to be too far from the market place and only honeydew melons remain of these early crops (Sutter Mutual Water Company [SMWC], 1992). Rice acreage started to increase so that by 1968 in excess of 26,000 acres were in rice production. Since that time, rice production has declined to between 15,000 acres and 19,000 acres for the last ten years. Processing tomatoes are also one of the major crops grown with more than 15,000 acres in production in 1993. Other crops have changed and many of the orchard crops that were productive in the early years are no longer grown. Today only small acreages of walnuts and apples are grown (SMWC, 1992).

Today, most of the agricultural land has been leveled to facilitate better water management and sustain crop productivity.

Climate

The climate of the study area is typical of a Mediterranean climate with hot, dry summers and cool, moist winters. The average monthly temperature ranges from 45 degrees Fahrenheit in January to 77 degrees Fahrenheit in August. There are wide ranges in the annual temperatures with recorded lows around 20 degrees and highs exceeding 110 degrees. Daily maximum temperatures in July and August normally range between 90 and 100 degrees Fahrenheit (SMWC, 1992).

Between 1963 and 1993 the precipitation ranged between 10 and 25 inches per year with the average over this 30 year period being 19 inches. The average low for this time frame was 9.72 inches, while the average high was 24.75 inches. Ninety percent of the rainfall, or about 13.5 inches, falls from November through April. The amount and distribution of rainfall in the study area creates a situation where the summer crops are irrigated (SMWC, 1992).

Although the growing season is long, during most years the area is subject to killing frosts. The frost-free growing season is about 220 days (SMWC, 1992).

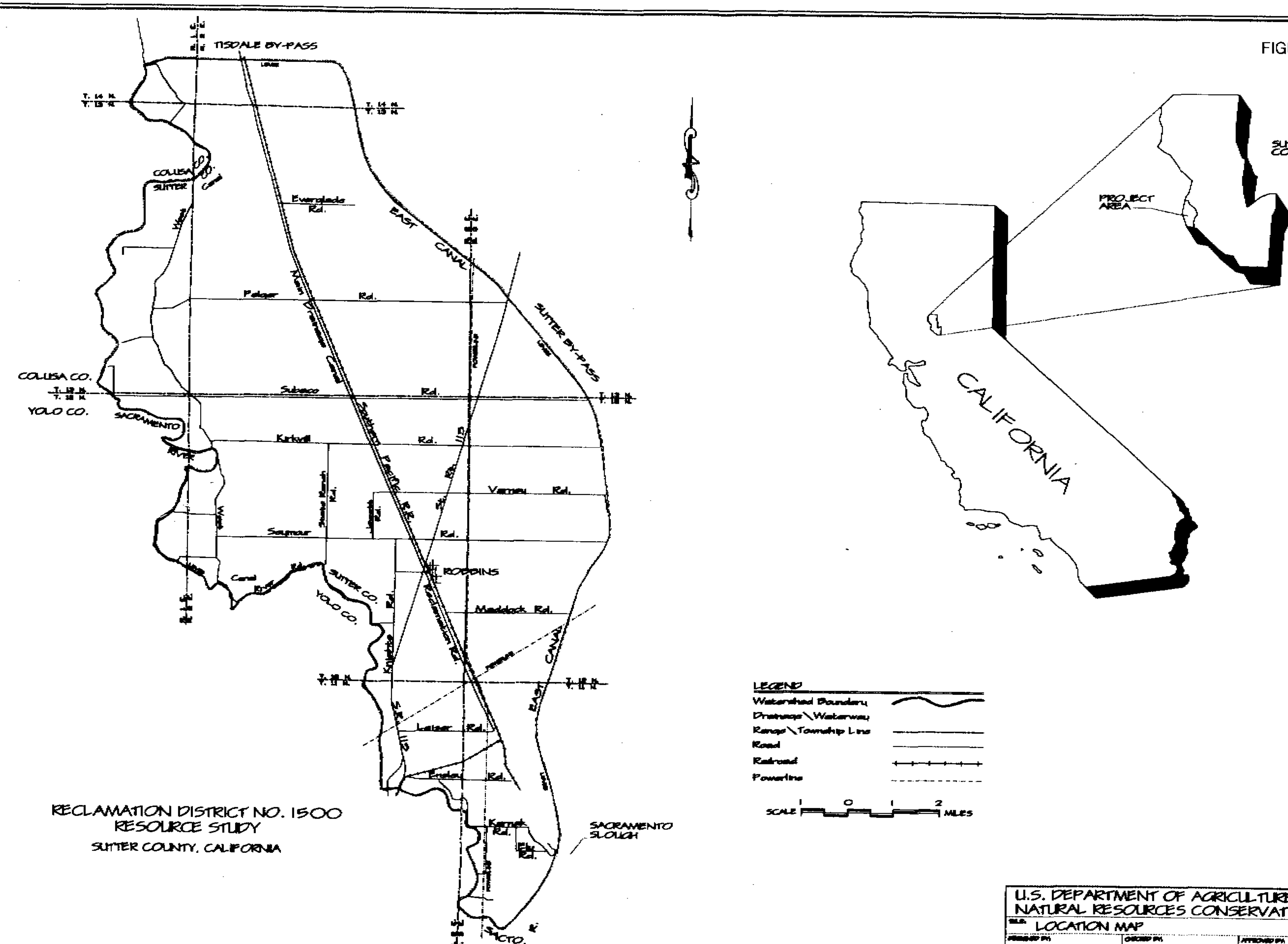
Soils

Prior to the construction of the levee system, floodwaters containing fine-grained sediments frequently spilled over into the lower-lying land adjacent to the Sacramento and Feather Rivers. Because of this, soil parent materials in the area are predominantly unconsolidated clay and silt. Coarser-grained parent materials occur along the periphery of the study area (SMWC, 1992).

The most commonly occurring soils in the study area are the Clear Lake, Sacramento, and Capay soils. These are deep, fine to very fine textured, somewhat poorly drained soils with restricted permeabilities. These soils must be carefully managed to minimize problems associated with slow intake rates, slow permeability, and soil tilth (SMWC, 1992).

Less commonly occurring soils are the Byington soil, which is formed from coarser-grained material and occupies stream channels and natural levees, and the Subaco and Marcum soils, which are formed from layers of coarse and fine-grained material and which occupy the outer edge or rim of the basin. Byington soils are medium-textured and often have a fluctuating water table within 60 inches of the soil surface. Subaco and Marcum soils are moderately to poorly drained and moderately deep to deep over a dense, massive, very slowly permeable subsoil (SMWC, 1992).

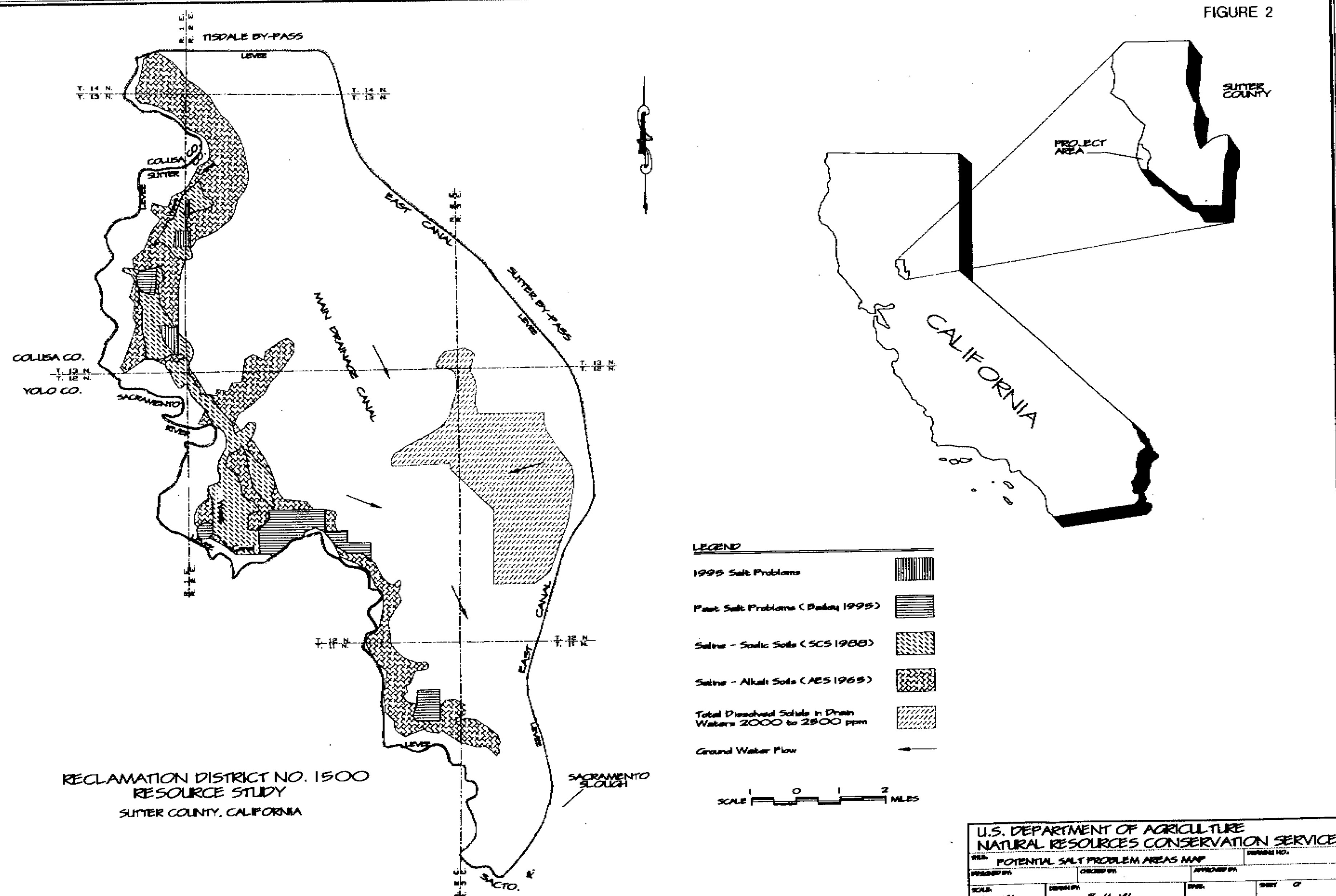
FIGURE 1



RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
LOCATION MAP

FIGURE 2



RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
POTENTIAL SALT PROBLEM AREAS MAP
SCALE: As Shown
DRAWN BY: T.M. Shaw

Depths from the soil surface to the shallow ground water table, measured during the winter of 1986-87, range from two to ten feet but may be as little as eighteen inches in recent alluvial soils. The basin and basin rim soils are not well suited to deep rooted crops (SMWC, 1992).

A pattern of past and present saline/sodic soils is seen in this area. The previously mentioned Byington silt loam is a saline/sodic soil.

The features shown on Figure 2 suggest a hydraulic connection between the Sacramento River and a band of silt loam soil paralleling the levee system along the river. This area had past salt problems but is now successfully cropped, the salinity problems apparently being overcome through proper irrigation and drainage.

Table 1 lists the soils occurring in the study area and describes some of the soil features related to water.

Geology

The study area is in the central portion of the Sacramento Valley. The major topographic feature is the Sutter Buttes. This feature is the erosional remnant of a laccolith and volcano formed during the late Pliocene time.

The other topographic features in the area are of low relief and are related to the fluvial deposition of the Sacramento River and its tributaries. Bryan (1923) estimated that before any reclamation had been accomplished, 60 percent of the Valley was subject to overflow including the river rim lands and a considerable portion of the low plains.

The trough underlying the Sacramento Valley consists of the thickest sediments and the most nearly complete late Mesozoic sections in North America (Olmstead and Davis, 1961). The Upper Jurassic, Lower Cretaceous, and Upper Cretaceous sequences have a thickness in excess of 10.6 miles. The Upper Cretaceous and pre-Pliocene sediments are tilted upwards at Sutter Buttes. Approximately 20 miles down, these sediments are vertically offset 500 feet by the N 70 degrees W striking, vertical Sutter Basin Fault.

It has been suggested that during the Late Paleocene Period, an inland sea was trapped in the Sacramento Valley, leaving a mound of connate water in the Kione Formation, Upper Cretaceous.

It is believed that this connate water, containing principally sodium and chloride, rises upwards through the Sutter Basin Fault under artesian pressure. The pressure is created by inflows of fresh water into the Kione sand formation at Sutter Buttes. The hydraulic head is estimated to be 262 to 426 feet (Tanji et al, 1975).

Socioeconomics

Sutter County encompasses an area of 385,720 acres. According to the 1990 Census of Agriculture (U.S. Department of Commerce, 1992), there are 318,000 acres of land in farms in Sutter County. The gross valuation of all agricultural products in Sutter County in 1993 totaled $292 million. Compared to all counties in California, Sutter ranks 18th in terms of the valuation of agricultural production. Fruit and nut crops continue to lead all commodity categories with a production value totaling $120 million. Rice is the leading field crop both in acreage and valuation.

TABLE 1 - SOILS FEATURES RELATED TO WATER

Soil Name and Map Symbol	Profile Depths (Inches)	Effective Rooting Depth (Inches)	Permeability (In/hr)	Available Water Capacity (In/In)	Runoff	Water Erosion Hazard	Shrink Swell Potential	Water Management Features Affecting Irrigation	Soil And Water Features Of Concern: Flooding Frequency	Flooding Duration	Flooding Months	High Water Table Depth Range Ft.	High Water Table Kind	High Water Table Months Highest	How Soils Drain	Bedrock Depth In	Bedrock Hardness	Cemented P Depth In	Cemented P Hardness
103 Byington silt loam	0-13 13-60	60+	0.6-2.0 0.6-2.0	0.16-0.18 0.15-0.19	very slow	slight	----	Wetness, erodes easily	Rare	----	----	2 to 3	Apparent	Dec-Apr		>60	----	----	----
104 Capay silty clay	0-36 36-60	60+	0.06-0.2 0.06-0.2	0.14-0.16 0.17-0.19	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	6 to 6	----	----	mod. well	>60	----	----	----
107 Capay Silty Clay	0-32 32-50	40-60	0.06-0.2 0.06-0.2	0.14-0.16 0.17-0.19	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	3 to 5	Perched	Dec-Apr	mod. well	40 - 60	Soft	----	----
108 Capay silty clay, wet	0-16 16-60	60+	0.06-0.2 0.06-0.2	0.13-0.16 0.16-0.19	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	4 to 6	Apparent	Jan-Dec	----	>60	----	----	----
110 Clear Lake silt loam	0-15 15-60	60+	0.6-2.0 0.06-0.2	0.17-0.19 0.12-0.16	very slow	slight	----	Percs slowly, erodes easily	Rare	----	----	3 to 6	Apparent	Dec-Apr	----	>60	----	----	----
111 Clear Lake silt loam, frequently flooded	0-15 15-60	60+	0.6-2.0 0.06-0.2	0.17-0.19 0.12-0.16	very slow	slight	----	Percs slowly, erodes easily, flooding	Frequent	Long	Dec-Apr	3 to 6	Apparent	Dec-Apr	----	>60	----	----	----
112 Clear Lake clay	0-42 42-60	60+	0.06-0.2 0.06-0.2	0.12-0.16 0.12-0.16	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	3 to 6	Apparent	Dec-Apr	poorly	>60	----	----	----
113 Clear Lake clay, frequently flooded	0-42 42-60	60+	0.06-0.2 0.06-0.2	0.12-0.16 0.12-0.16	very slow	slight	high	Slow intake, percs slowly, flooding	Frequent	Long	Dec-Apr	3 to 6	Apparent	Dec-Apr	poorly	>60	----	----	----
115 Clear Lake clay, siltstone substratum	0-42 42-48 48	36 - 60	0.06-0.2 0.06-0.2 ----	0.14-0.16 0.14-0.16 ----	very slow	slight	high	Slow intake, percs slowly	Rare	----	----	3 to 5	Perched	Jan-Dec	poorly	40-60	Soft	----	----
117 Columbia fine sandy loam	0-14 14-60	60+	2.0-6.0 2.0-6.0	0.1-0.12 0.1-0.12	very slow	slight	----	Droughty	Rare	----	----	3 to 5	Apparent	Dec-Apr	----	>60	----	----	----
118 Columbia fine sandy loam, channeled	0-14 14-60	60+	2.0-6.0 2.0-6.0	0.1-0.12 0.1-0.12	very slow	severe	----	Droughty, Flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec-Apr	----	>60	----	----	----
119 Columbia fine sandy loam, clay substratum	0-15 15-52 52-60	40 - 60	2.0-6.0 2.0-6.0 0.06-0.2	0.1-0.12 0.8-0.11 0.14-0.16	very slow	slight	----	Droughty, percs slowly	Rare	----	----	3 to 5	Apparent	Dec-Apr	----	>60	----	----	----
121 Columbia fine sandy loam, frequently floods	0-14 14-60	60+	2.0-6.0 2.0-6.0	0.1-0.12 0.1-0.12	very slow	severe	----	Droughty, flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec-Apr	----	>60	----	----	----
122 Columbia loam	0-25 25-60	60+	0.6-2.0 2.0-6.0	0.14-0.16 0.08-0.11	very slow	slight	----	Favorable	Rare	----	----	3 to 5	Apparent	Dec-Mar	----	>60	----	----	----
133 Hollilipah loamy sand	0- 8 8-60	60+	6.0-20.0 6.0-20.0	0.06-0.08 0.06-0.09	very slow	slight	----	Droughty, slow intake, soil blowing	Rare	----	----	6 to 6	----	----	Somewhat excessive	>60	----	----	----
138 Liveoak sandy clay loam	0-13 13-53 53-60	60+	0.6-2.0 0.6-2.0 2.0-6.0	0.14-0.16 0.14-0.16 0.08-0.11	very slow	slight	----	Favorable	None	----	----	6 to 6	----	----	Well	>60	----	----	----
141 Marcum clay loam	0-16 16-28 28-40 40-43 43	40 - 60	0.2-0.6 0.2-0.6 0.06-0.2 0.2-0.6 ----	0.17-0.19 0.17-0.19 0.14-0.16 0.17-0.19 ----	very slow	slight	high	Percs slowly	None	----	----	6 to 6	----	----	Moderately Well	40-60	Soft	----	----
143 Marcum-Gridley clay loams	0-16 16-28 28-40 40-43 43	40 - 60	0.2-0.6 0.2-0.6 0.06-0.2 0.2-0.6 ----	0.17-0.19 0.17-0.19 0.14-0.16 0.17-0.19 ----	very slow	slight	high	Percs slowly	Rare	----	----	6 to 6	----	----	Moderately Well	40-60 (Marcum) 20-40 Gridley)	Soft Soft	---- ----	---- ----
144 Nueva loam	0-17 17-42 42-60	60+	0.6-2.0 0.6-2.0 0.2-0.6	0.15-0.17 0.14-0.16 0.17-0.20	very slow	slight	----	Erodes easily	Rare	----	----	4 to 6	Apparent	Dec-Apr	----	>60	----	----	----
153 Oswald clay	0-15 15-33 33	20 - 40	0.06-0.2 0.06-0.2 ----	0.14-0.17 0.14-0.17 ----	very slow	slight	high	Wetness, slow intake, percs slowly	Rare	----	----	1.5 to 3.5	Perched	Dec-Apr	Moderately Well	20-40	Soft	----	----
161 Shanghai fine sandy loam	0-15 15-60	60+	0.6 - 2.0 0.6 - 2.0	0.12-0.14 0.15-0.19	very slow	moderate	low moderate	Erodes easily, flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec.-Apr.	Somewhat poorly	>60	----	----	----
162 Shanghai silt loam	0- 9 9-60	60+	0.6-2.0 0.6-2.0	0.15-0.19 0.15-0.19	slow	moderate	----	Erodes easily	Rare	----	----	3 to 5	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
163 Shanghai silt loam	0-12 12-41 41-60	40 - 60	0.6-2.0 0.6-2.0 0.06-0.2	0.15-0.19 0.15-0.19 0.14-0.16	very slow	slight	----	Percs slowly, erodes eaasily	Rare	----	----	4 to 6	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
164 Shanghai silt loam	0-12 12-41 41-60	40 - 60	0.6-2.0 0.6-2.0 0.06-0.2	0.15-0.19 0.15-0.19 0.14-0.16	very slow	moderate	----	Percs slowly, erodes eaasily	Frequent	Long	Dec-Apr	4 to 6	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
165 Shanghai silt loam	0-11 11-60	60+	0.6-2.0 0.6-2.0	0.15-0.19 0.15-0.19	very slow	moderate	----	Erodes easily, flooding	Frequent	Long	Dec-Apr	3 to 5	Apparent	Dec-Apr	----	>60	----	----	----
166 Shangai silt loam wet	0- 8 8-60	60+	0.6-2.0 0.6-2.0	0.15-0.19 0.15-0.19	very slow	moderate	----	Wetness, erodes easily, flooding	Frequent	Long	Dec-Apr	2.5 to 5	Apparent	Jan-Dec	Somewhat poorly	>60	----	----	----
167 Shanghai silty clay loam	0-38 38-60	60+	0.2-0.6 0.6-2.0	0.17-0.20 0.15-0.19	very slow	slight	----	Erodes easily	Rare	----	----	3 to 5	Apparent	Dec-Apr	Somewhat poorly	>60	----	----	----
173 Subaco clay	0-13 13-26 26	20 - 40	0.06-0.2 0.06-0.2 ----	0.14-0.16 0.14-0.16 ----	very slow	slight	high	Wetness, slow intake, percs slowly	Rare	----	----	1.5 to 3.5	Perched	Dec-Apr	Somewhat poorly	20-40	Soft	----	----
174 Tisdale clay loam	0-11 11-31 31	20 - 40	0.2-0.6 0.2-0.6 ----	0.17-0.19 0.14-0.19 ----	very slow	slight	----	Depth to rock	None	----	----	6 to 6	----	----	Well	20-40	Soft	----	----
175 Yuvas loam	0-16 16-24 24-38 38	20 - 40	0.6-2.0 < 0.06 ---- ----	0.14-0.16 0.06-0.08 ---- ----	very slow	slight	----	Percs slowly, depth to rock, cemented pan	None	----	----	6 to 6	----	----	Well	20-40	Soft	20-38	Thick

The population of Sutter County in 1994 was 73,100 with about half of the people living in unincorporated regions of the county. The per capita income in 1992 was $18,100 which is 85 percent of the California average.

According to the 1990 census, using the corresponding tract which is larger but includes the study area, about 78 percent of the population is white, 2 percent is Native American and 20 percent of the citizens are listed as other. Of this population, 27 percent identified themselves as being of Hispanic origin.

The study area is a highly productive rural area consisting of approximately 155 farm landowners and 145 residential landowners. Many of the farm operator families have been farming in the area since the 1930s. A typical farming operation includes 1,500 to 3,000 acres with a significant portion of the land leased. The gross crop value generated from this area is approximately $60 to $72 million (SMWC, 1992).

Land Use and Crops

Table 2 provides a breakdown of the acreages of the various crops grown in the study area in 1993. Although cropping patterns have changed to some extent over the years, the types of crops and acreages grown have basically stayed the same. Yearly acreage changes are due to rotations by the individual ownerships. Local landowners feel that in the coming years the acreages and types of crops grown in the basin will remain the same unless water availability and costs change dramatically.

Most tillage operations for all crops in the basin are conventional. Much of the sediment from cultivation and irrigation practices is kept from reaching drainage ways and sumps by erosion control drop structures at the ends of fields. Sediment reaching the drains and sumps is removed periodically and spread on the fields. To most landowners and managers erosion is not perceived as a problem. Removal and spreading is thought of as part of the normal operation and cost of doing business.

The two major crops are processing tomatoes grown in rotation with wheat, corn, safflower, and beans and rice. Rice may be grown in rotation with crops such as wheat, safflower, beans, and melons though some growers grow rice seven to eight years in a row.

Rice stubble decomposition is being practiced throughout the basin because stubble burning is being phased out by the State of California. Rice stubble needs to decompose before the next year's crop is grown. In the past burning was an easy, fairly inexpensive method of removing stubble but its effects on air quality have proved intolerable. New technology is being tried to find better methods of decomposition. Many landowners chop and incorporate the stubble to a depth of 10 to 20 inches and leave the field dry except for winter precipitation or submerge the field under water throughout the winter. Currently one- to two-acre feet of irrigation water is being used to flood rice fields for decomposition. Some landowners feel that flooding is the best way to decompose rice stubble and provides other side benefits such as additional habitat for waterfowl. Rice decomposition costs $25 per acre for flooding and $50 per acre to incorporate stubble into the soil. If both methods are used, costs can average $75 per acre.

Orchards in the basin are mostly walnuts grown on the higher ground along the Sacramento River. Soil along the river is deeper and has better drainage than the majority of the soils in the area. Some orchards have tile drains six to eight feet below the surface because the water table is high and affects root growth. The average life of a walnut orchard is 30 years. Trees are either replaced in large blocks or the whole orchard is replaced. The average yield for walnuts is two to three tons per acre. The orchard floor is mowed and noncultivated with the tree rows strip sprayed.

TABLE 2: Landuse Categories and Acreages for Sutter County in 1993

RECLAMATION 1500 LANDUSE CATEGORY	ACRES
RICE	19,322
TOMATO	15,035
SAFFLOWER	8,262
WHEAT	4,625
MELON	4,526
WHEAT BEANS	3,682
RICE DECMP	3,101
BEANS	2,893
SET ASIDE (Idle)	1,735
WALNUT	922
CORN	836
WHEAT MILO	508
SEED	433
WHEAT MELON	261
SUNFLOWER	249
BEETS	243
WHEAT SAFFLOWER	217
ALFALFA HAY	203
SAFF PREIR	155
WHEAT PREIR	153
SORGHUM	85
PASTURE	76
URBAN	33
APPLES	31
NATURAL AREA	26
SURFACE WATER	15
FARMSTEAD	9
TOTAL	**67,636**

Water Quality

Water quality concerns in the area center on salinity. Arsenic has been a problem in the ground water under the town of Robbins, but ground water is not generally used for agriculture and arsenic has not been detected in the drains. The District monitors its drains for herbicides to insure that herbicide concentrations meet current standards.

The water supply from the river is of excellent quality and averages 130 micromhos/cm electrical conductivity (EC). The water finds its way into the drains and picks up volume and salinity from subsurface water. The EC of the water at the main drain before and after the irrigation season is typically ten times greater than that of the supply water and about five times greater during the irrigation season. The water used for crop irrigation apparently dilutes the salt concentration in the drain water. The irrigation season runs from April through October. During the irrigation season from 1987 to 1992 the EC of the main drain at Karnak varied from 380 to 780 micromhos/cm. In the winter the EC ranged from 420 to 1500 micromhos/cm.

Biology

The pre-agricultural vegetation of southern Sutter County was a patchwork of California prairie, tule marsh, and riparian forest (Kuchler, 1964). The California prairie was probably the most common of the three types, and consisted of a perennial bunch grass prairie with annual grasses and herbs interspersed. Purple needlegrass dominated the valley grassland along with creeping wild rye, blue wild rye, Idaho fescue, California oniongrass, California bluegrass, and others (Barbour and Major, 1977). This grassland supported tule elk, pronghorn antelope, and California grizzly bear, and provided nesting habitat or forage areas for waterfowl like mallards and Canada geese.

The low-lying ground within the grassland was probably covered by tule marsh. This freshwater emergent wetland was dominated by common tule and cattail with **Carex** and **Juncus** species as lesser components. These marsh areas were extensively used by tule elk and migratory birds, especially waterfowl.

The natural banks along the Sacramento and Feather Rivers supported extensive areas of riparian forest. The mixed riparian forest was dominated by Fremont cottonwood with an understory of Gooding's black willow near the river with increasing amounts of valley oak, California sycamore, California black walnut, box elder, red willow, and yellow willow along the top and outside of the natural levees. Vertical structure was added by shade-tolerant shrub species like Oregon ash, buttonwillow, blue elderberry, and poison oak. Areas with woody vines like wild grape and virgin's bower had a distinct jungle character. Field examinations of existing vegetation indicate the upland areas along the natural banks supported large valley oak stands which was probably graded into a savanna at the interface with the prairie.

This mosaic of native vegetation has been changed as the study area was converted to its present agricultural character. The California prairie and its associated large mammals has been reduced, and only small remnants of tule marsh, riparian forest, or valley oak woodland remain. This change is not unique to the study area, but is typical of the widespread change in the Sacramento Valley. The loss of riparian habitat and its ability to support diverse insect and vertebrate populations has had a severe impact on some species. In addition to the species already gone from the area, several are at very low levels and many are presently quite rare and even listed as State or Federal threatened or endangered species. Those species within or near the study area include the western yellow-billed cuckoo, Swainson's hawk, bank swallow, wood duck, bald eagle, giant garter snake, western pond turtle, California tiger salamander, California red-legged frog, Chinook salmon, valley elderberry, longhorn beetle, and the California hibiscus.

The agricultural development of the area has favored other wildlife species. Migratory waterfowl are doing very well in those areas where rice, wheat, barley, milo, corn, and beans are being grown. Grain plants which are planted in the fall and not harvested until May or June provide good nesting habitat for waterfowl, especially if they are near rice fields. The rice fields provide very good habitat throughout the summer and into the fall and, in some cases, through the winter. This habitat mix attracts and supports some of the highest waterfowl densities in the state. Ring-necked pheasants, an introduced species, also do well in the drier parts of this habitat mix and make good use of ditch banks and irrigation levees for nesting. The ditches themselves provide good habitat for blue and channel catfish, carp, crayfish, and bullfrogs. These aquatic species support a local sport fishery which is accessible to the public.

Using "A Guide to Wildlife Habitats of California" (Mayer and Laudenslayer, 1988), today's major habitat types are cropland, orchard, and pasture. The tule marsh remnant is present as fresh emergent wetland, and the riparian forest is present as patches of valley foothill riparian or small areas of valley oak woodland. The wildlife habitat relationships (WHR) database provides a listing of animal species commonly associated with these habitat types in Sutter County, and a copy of the listing is included in Appendix A.

The "California Natural Diversity Database Rare Find Report" noted the occurrence of the Swainson's hawk, western yellow billed cuckoo, willow flycatcher, bank swallow, tricolored blackbird, giant garter snake, great valley mixed riparian forest, and California hibiscus in or near the study area. The only listings actually found in the study area are the Swainson's hawk and the bank swallow. Field checks verified the Swainson's hawk to be in the study area along the Sacramento River between the Yolo Bypass and the Tisdale Bypass. There are several bank swallow colonies along the Sacramento River with at least one on the Sutter County side. This nesting site is located on a wide meander just upstream from the pumping plant at State Ranch Bend, near one of few remnant riparian vegetation sites on the Sutter County side of the Sacramento River. No bank swallows were observed as the site was checked after the active nesting season. The report's comments noted that the tricolored blackbird colonies had disappeared due to habitat loss, and no tricolored blackbirds were observed during field inventories. Table 3 lists the threatened and endangered species cataloged in the study area.

TABLE 3 - Federal and State listed threatened, endangered, and candidate species that are known to occur in the Reclamation District 1500 Project Area.
December 1994

NAME Scientific	Common	FEDERAL STATUS	STATE STATUS
INVERTEBRATES			
Desmocerus californicus dimorphus	Valley elderberry longhorn beetle	T	
FISHES			
Onchrhynchus tsawytscha	Winter-run chinook	T	E
AMPHIBIANS			
Ambystoma californiense	California tiger salamander	C1	
REPTILES			
Thamnophis gigas	Giant garter snake	Proposed T	T
Clemmys marmorata marmorata	Northwestern pond turtle	C2	P
BIRDS			
Buteo swainsoni	Swainson's hawk	P	T
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	P	E
Empidonax traillii	Willow flycather	E	E
Riparia riparia	Bank swallow	P	T
Agelaius tricolor	Tricolored blackbird	C2	SC
MAMMALS			
PLANTS			
Hibiscus lasiocarpus	California hibiscus	C2	

STATUS:

E	Endangered : Listed as Endangered
T	Threatened : Listed as Threatened
C1	Candidate 1 : Sufficient biological data to support a proposal to list as threatened or endangered
C2	Candidate 2 : Existing information may warrant listing, but substantial biological support for listing is lacking.
SC	Special concern : California species that has either declined in numbers or its range reduced, population is monitored to see if more study is warranted.
P	Protected either by Federal or State Laws/Regulations

See the Wildlife Habitat Relationships printout for a complete listing of all potential species that could possibly occur in the area.

SECTION III

WATER RESOURCES INVENTORY

History of Irrigation and Drainage Systems in the Basin

In the early 1900s, the plan of reclamation consisted of the construction of levees as protection against overflow from flood waters; the construction of levee and bank protection work to prevent erosion of the banks and levees; the construction and operation of a pumping plant for the disposal of seepage water and rain, and later irrigation runoff; and the construction of a drainage system to conduct the seepage and rain waters to the pumping plant at the lower end of the basin.

The original levees that were constructed had a height of 20 to 25 feet above ground elevation for the bypass levees and 12 feet for the river levees. In the late 1930s, the bypass levees were weakened but were later rebuilt and raised eight feet in the early 1940s. The Sacramento River levees were also reconstructed and brought up to federal standards in the 1940s and 1950s. Of the 34 miles of river levees only four and one-half miles have not been reconstructed to date.

After the levees were built, the drainage system for the basin was constructed. This system consisted of a pumping plant, the main drainage canal, and laterals and sublaterals located to drain every one-quarter section of land conveying water to the main drain and the pumping plant. These drains were designed and built to keep the water table, in all cases, five feet below the ground surface. In 1922, a gravity outlet was constructed at the lower end of the drainage canal to automatically drain irrigation waters from the basin during low summer flows of the Sacramento River. This allowed the pumping plant to be shut down in summer months and saved operating costs during that time. The drainage system was designed to work with an irrigation system which was considered a necessity from the inception of the reclamation work.

Shortly after the levees and drainage systems were built, the irrigation system, including pumping plants, was completed by the Sutter Basin Corporation, a private corporation. The main irrigation system was laid out using a plane table survey with six-inch contour intervals. The system consisted of main canals, lateral canals, and sublaterals designed to deliver water to each individual farm. Delivery was designed to provide irrigation to each 40-acre tract at an elevation at least one foot higher than the highest land in the tract. The highlands along the Sacramento River in private ownership, with a few exceptions, were not covered by the system. Nearly all of the main structures, such as headgates, checks, drops, turnouts, or delivery structures, were built of reinforced concrete. The larger structures were equipped with screw stem gates while the other structures had redwood flashboards.

By 1926, the basin also had 180 miles of graded roads, 136 miles of graveled roads, and four miles of concrete paved roads.

Surface Water Resources

Sources

Most of the irrigation water is diverted from the Sacramento River under appropriative rights that date back to 1917 (SMWC, 1992). Later, in 1964, the Company and several individual landowners secured water under a contract with the U.S. Bureau of Reclamation (BOR). A smaller amount of water is provided by drainwater reuse within the service area. There are also some individuals pumping directly out of the river and a small number of wells.

Irrigation Delivery Network

In 1990, 197,200 acre-feet of water were diverted through canals from the Sacramento River by the Company. Figure 3 is a map of this network of canals. The Company maintains and operates three pumping plants: Tisdale Pumping Plant (906 cfs total capacity), State Ranch Bend Pumping Plant (125 cfs), and Portugese Bend Pumping Plant (100 cfs). In addition, the Company operates eight booster pumps and one internal recirculation system with a total combined capacity of 290 cfs per day. These pumps are located in the central and northeast portion of the area for the purpose of drainwater reuse.

There is a total of 56 miles of irrigation water delivery canals and 144 miles of laterals in the study area. Water is distributed through this system of unlined canals by gravity. Due to topography, the canals have an average slope of three inches per mile and a velocity of 1.0 foot per second or less (SMWC, 1992). Portions of the main channels are chained during the irrigation season to control weeds.

Company policy states that irrigation water delivery to growers requires a 48-hour advance notice and a 12-hour advance notice for shut off. The Company estimates a water order from the BOR on Monday of each week during the irrigation season. The area is divided into six service areas with six ditch riders working together to achieve flexibility in delivery and service so the resulting system is much more flexible than the existing policy.

Water Measurement

Water pumped from the river is measured at the pumping plants. Meters are installed, maintained, and monitored by the BOR at these locations with the exception of the Tisdale plant, which is measured with a series of rating tables. All field deliveries are measured using Armco Gate Opening Rating Tables. The daily deliveries are recorded by the ditch rider and tabulated for billing.

Irrigation Efficiencies

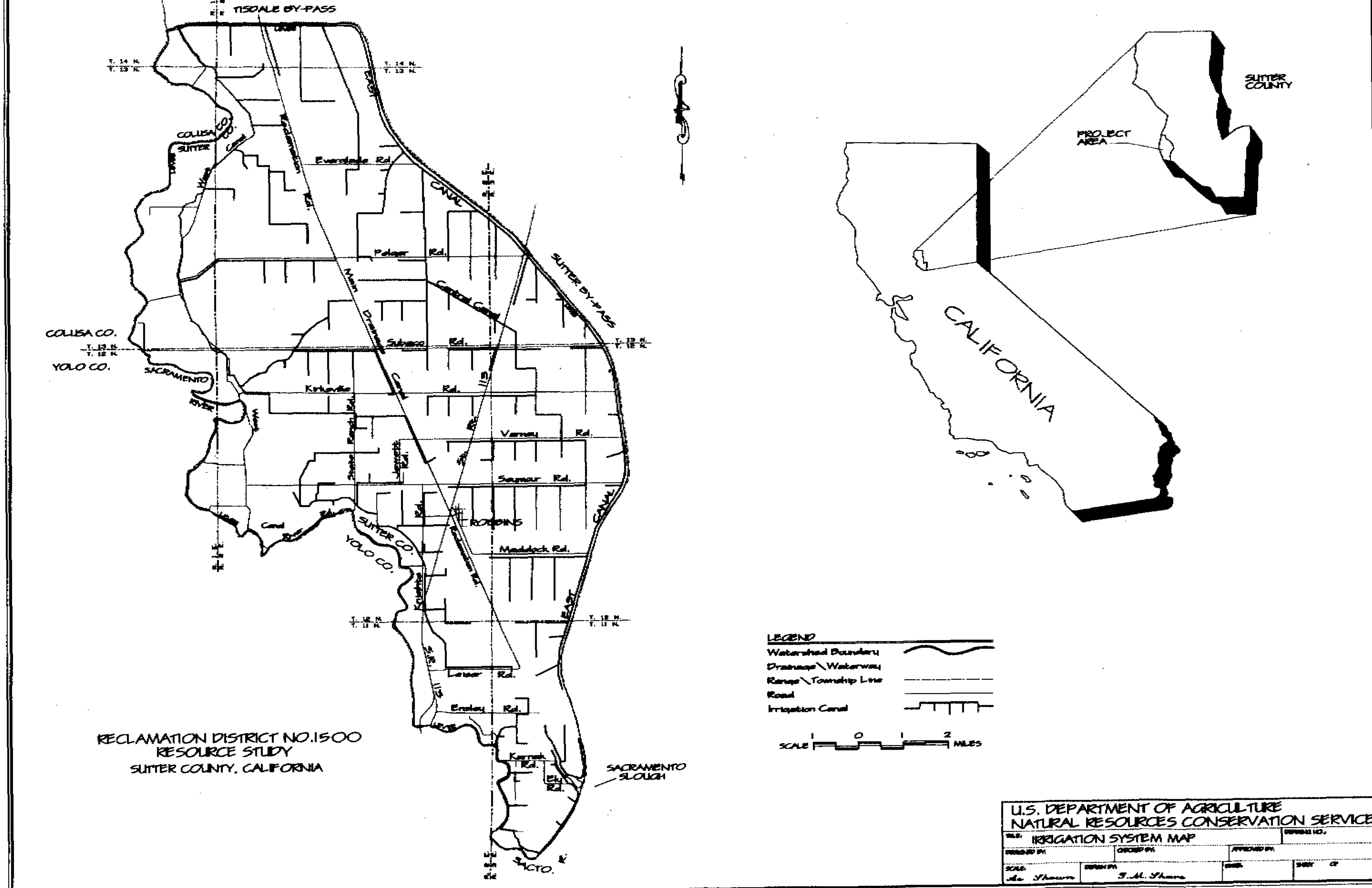
Efficient on-farm irrigation water use is concerned with four things:

1. how well the irrigation system distributes the water over the field into the soil, also called distribution uniformity;
2. how much water leaves the end of the field (surface loss);
3. how much of the applied water goes below the root zone (deep percolation); and
4. how often the field is irrigated.

The distribution uniformity is influenced by the irrigation system design and operation. Surface irrigation methods have distribution uniformities which can be quite high on medium and fine textured soils if stream sizes are large enough. Furrow systems trade off surface losses and deep percolation losses. Surface systems can have distribution uniformities in excess of 95 percent. Sprinkler irrigation systems have distribution uniformities between 70 and 80 percent. Surface systems usually need a minimum application to function well. The frequency of irrigation is the single most important factor in maximizing irrigation efficiency. If a manager irrigates too frequently and too much water is applied, the irrigation efficiencies will be low. An irrigation efficiency of 80 percent is considered quite good.

There are two mechanisms for irrigation water loss - deep percolation and tailwater. Tailwater loss is easy to see; it is the water leaving the field on the surface during and after the irrigation set. Tailwater reuse systems and properly designed sprinkler systems eliminate this loss. Tailwater volume is minimal at the start of an irrigation and is at a maximum at the end of the irrigation. Deep percolation loss is the water which goes past the root zone of the crop. Early in the irrigation season, water may go past the immature crop's root zone but still be used as the root zone goes deeper. Deep percolation losses are stored in the soil profile and delivered to the drainage system over a period of time. Losses are reduced by minimizing these losses through system improvements and management.

FIGURE 3


TISDALE BY-PASS
SUTTER BY-PASS
EAST CANAL
Everglade Rd.
Pelger Rd.
Central Canal
Main Drainage Canal
Reclamation Rd.
Subaco Rd.
Kirkville Rd.
Varney Rd.
Seymour Rd.
ROBBINS
Maddock Rd.
Leiser Rd.
Ensley Rd.
Karnak Rd.
Ely Rd.
COLUSA CO.
YOLO CO.
SUTTER CO.
SACRAMENTO RIVER
SACRAMENTO SLOUGH
SACTO.
T. 14 N.
T. 13 N.
T. 12 N.
T. 11 N.
CALIFORNIA
PROJECT AREA
SUTTER COUNTY
LEGEND
Watershed Boundary
Drainage\Waterway
Range\Township Line
Road
Irrigation Canal
SCALE
1
0
1
2
MILES
RECLAMATION DISTRICT NO.1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
IRRIGATION SYSTEM MAP
As Shown
J. M. Shaw

Rice culture is unique among all the crops in the basin. Rice has a high evapotranspiration rate, greater than some other crops. However, the need of the crop to be in a fully saturated field also affects how much water is applied to the crop. The continual flow of water on the field is governed by two factors, the crop evapotranspiration and water percolation. Water loss goes from the field down gradient to the drainage system; in some cases there are other crops between the rice field and the drainage net. The rice fields raise the water table in the surrounding fields because the water table becomes the water surface of the rice field. The water table is also manipulated by raising the water surface in the drainage ditches using water control structures.

Field characteristics vary throughout the basin. Soils, crop selection, depth to water table variability through the irrigation season, field slope or lack of it, and surrounding crops, all influence irrigation operations throughout the season. If the water table approaches the root zone of the crop, the crop can obtain water without irrigation. For example, less water is applied to all the melons than the crop needs. While melons are all under irrigated in the basin, it is a successful crop because it meets its water needs from the water table. Seventy-one of the 136 growers of tomatoes, melons, and beans are able to apply less than the estimated crop needs. While underapplication of water is usually a poor technique with implications of increasing soil salinization and future declining yields, this has not been the case in this area due to the amount of rainfall the area receives and the presence of the drainage system. Winter rainfall and the lowering of the water table helps to remove salts from the fields. Problems might occur in double cropped fields and in drought years when these salts concentrate and are not leached from the soil.

The average crop irrigation requirement for the period 1981 through 1990 was approximately 85,800 acre-feet per year. Dividing the average crop irrigation requirement for the period by the average irrigation delivery of 172,800 acre-feet yields a service area-wide average on-farm efficiency of approximately 50 percent. Average efficiencies from 1991 to 1994 were up to 60 percent. On-farm efficiencies ranged from 45 to 55 percent with open ditch systems having lower efficiencies than piped systems (SMWC, 1992). This is not necessarily undesirable due to the fact that drainage is returned to the river for use by downstream users or instream flows.

On-Farm Irrigation Practices

Basin flood, furrow, and sprinkler irrigation are the most common methods of irrigation. In some parts of the study area the water table is only a few feet from the surface and many of the crops utilize this water by subsurface irrigation and require less surface irrigation water.

Processing tomatoes are grown on five-foot beds with one or two rows of vines per bed, depending on the variety of the tomato grown. Irrigation is mostly by sprinkler throughout the growing season although some acres are sprinkled the first two irrigations and then furrow irrigated the remainder of the growing season. All other crops are surface irrigated. Safflower and wheat are usually dry cropped with one pre-irrigation, if needed.

Rice is basin irrigated with berms generally following the contour of the field. Water management has been improved since water cannot be released from the field into drainage ditches until it is held in the field for a minimum of 30 days after pesticide applications. This is done to reduce the pesticides used in rice culture from reaching the Sacramento River in the runoff from the rice fields.

Irrigation of orchards is mostly done by solid set impact sprinklers, hand moved impact sprinklers, or micro-sprinklers. A few of the orchards are border irrigated.

Present irrigation and drainage practices have kept salt levels in the soil down to a manageable level.

Due to the low EC of the irrigation supply water, it was estimated that less than one percent of the applied irrigation water is needed for leaching purposes, even for the more sensitive crops. The leaching requirement is based on soil salinity equilibrium conditions throughout the irrigated area. The leaching requirement for connate water suppression has not been estimated. Continual productivity indicates the leaching requirement is being maintained. Actual soil leaching requirements vary throughout the area (SMWC, 1992).

Drainage Network

The drainage network of unlined ditches outletting at the Karnak pumping plant has a capacity of 3,800 acre-feet per day with some possible additional gravity discharge. There are 18 miles of unlined main drainage canals and 425 miles of unlined laterals. Figure 4 is a map of the drainage network.

The drainage system consists mostly of open ditches carrying irrigation runoff, seepage from the river, connate water, and winter rainfall runoff. The system has collector and sub-collector drains varying in depth from six to ten feet with bottom widths from three to ten feet. There are also a few subsurface tile drains installed near the river where orchards are planted.

Ground Water Resources

Approximately 38 wells have been drilled in the project area. The depth of drilled wells ranges from 72 feet to 1,500 feet and measured total dissolved solids (TDS) concentrations range from 248 to 5,970 mg/l. Many of these wells have been abandoned. A mound of artesian connate water has been identified in the project area (Tanji, 1975). Insufficient data exists to delineate boundaries between the freshwater and saltwater underlying the study area. Figure 5 is a cross-section across the basin depicting the known and conjectured relationships of river, connate, and ground waters.

The high water table in the study area consists of seepage from the river, subsurface interbasin inflow from the surrounding area, and rising connate water under artesian pressure. Due to its high salt content, the ground water is not used for irrigation except in limited areas along the Sacramento River, where the salt content can be much lower.

One potential source for salt buildup in the ground water is the upward movement of deep lying connate water driven by freshwater under an artesian head.

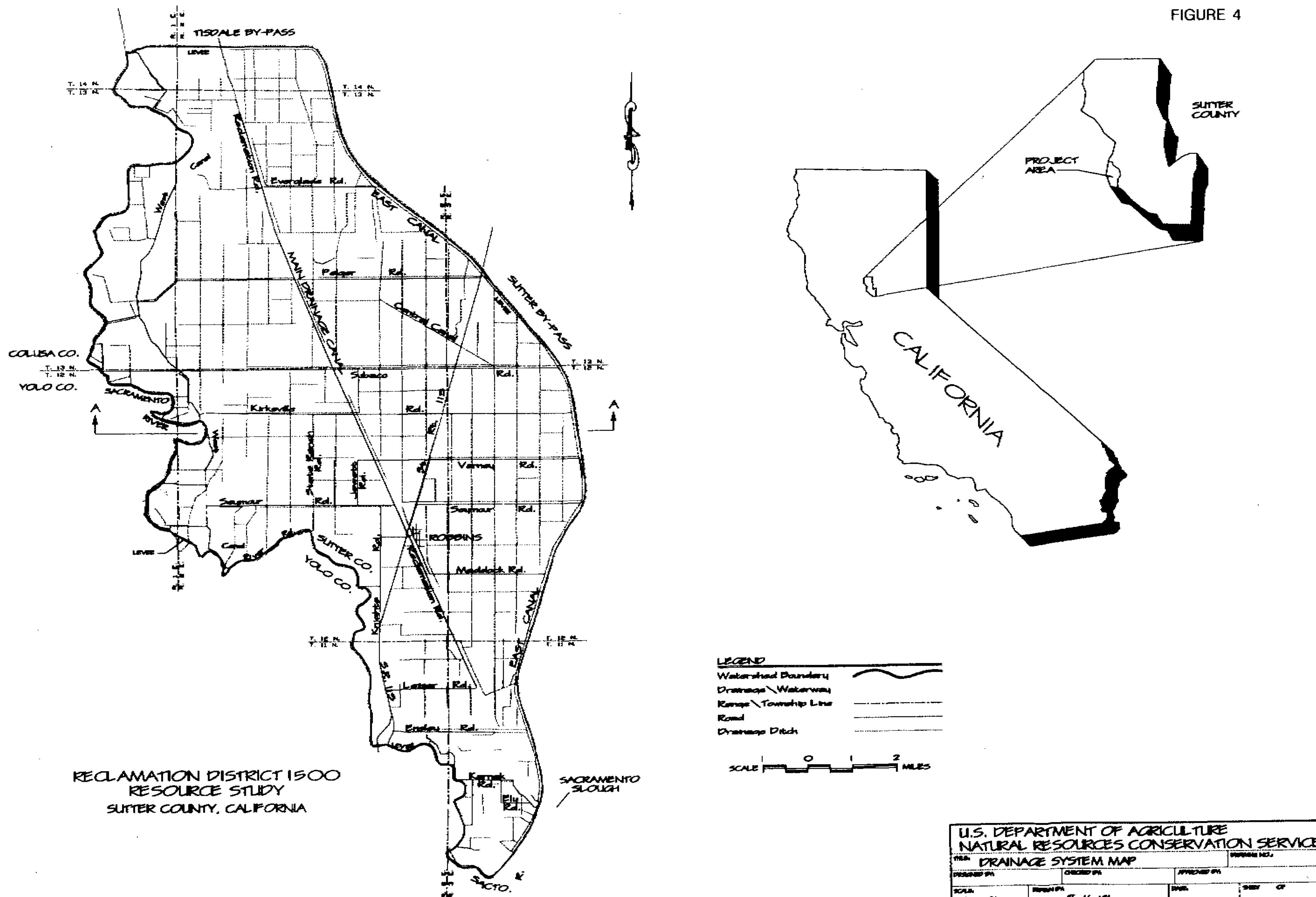
The concentration of salts increases with depth below ground. Ten to 20 feet below the surface the EC ranges from 1,000 to 4,000 micromhos/cm while 100 to 300 feet below surface the EC range increases from 8,000 to 13,000 micromhos/cm (Tanji, 1975).

The salt-laden ground water seeps into the drain ditches and causes an increase in EC in the drains. The salt concentration in the main drain is typically much higher during the winter than during the irrigation season. The good quality irrigation water dilutes the salty ground and drain waters. The irrigation season runs from April through October. During this season from 1987 to 1992 the EC of the main drain at Karnak varied from 380 to 780 micromhos/cm. In the winter the EC ranged from 420 to 1500 micromhos/cm. Figure 6 shows the measured EC of drain ditches in the area in January and February of 1972 (Tanji, 1975).

Connate Water

In 1972, based on the EC of drain waters, Ken Tanji delineated the area shown on Figure 2 having total dissolved solids (TDS) ranging from 2,000 to 2,500 parts per million (ppm) (Tanji, 1972).

FIGURE 4



RECLAMATION DISTRICT 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
DRAINAGE SYSTEM MAP

FIGURE 5

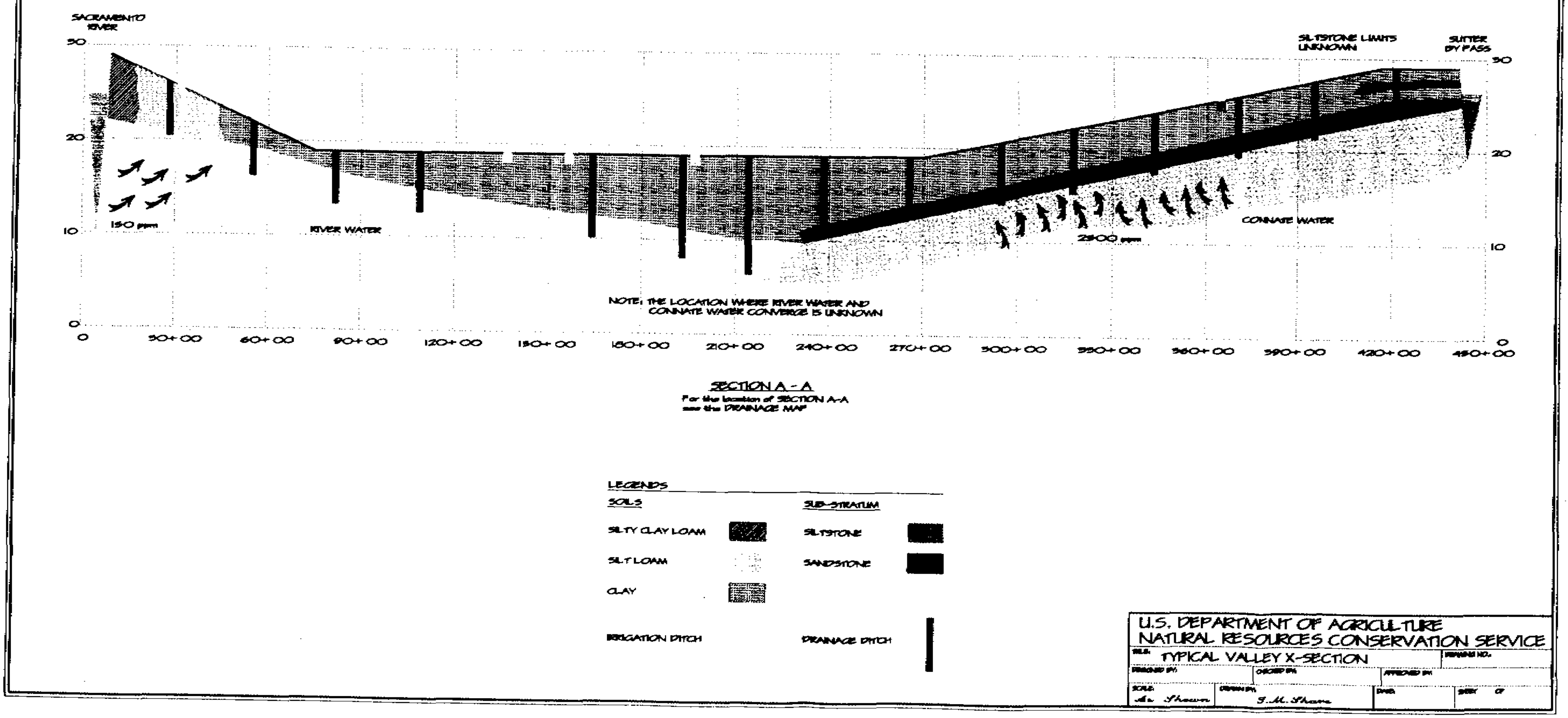
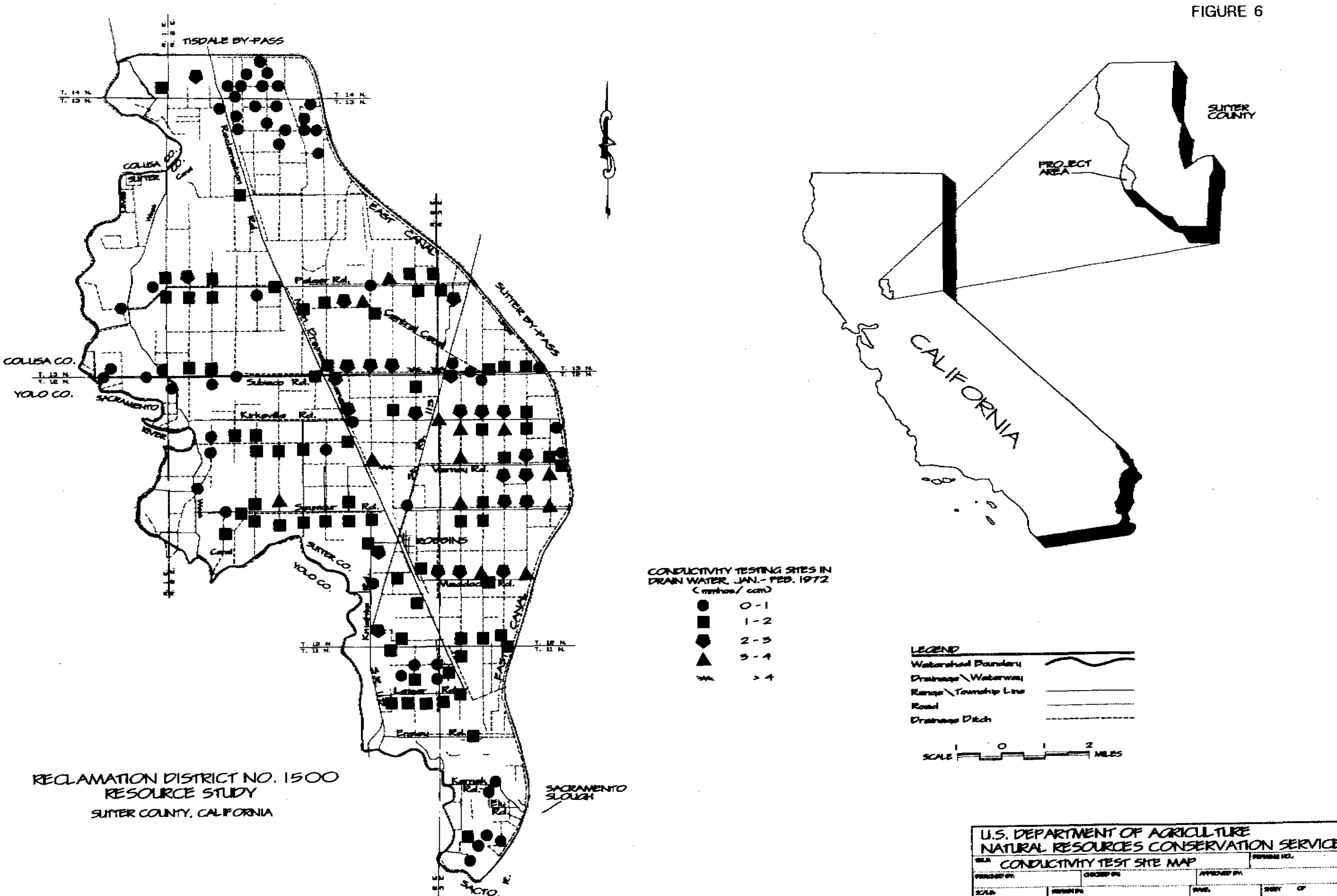

SACRAMENTO RIVER
SUTTER BY PASS
SILTSTONE LIMITS UNKNOWN
150 ppm
RIVER WATER
2900 ppm
CONNATE WATER
NOTE: THE LOCATION WHERE RIVER WATER AND CONNATE WATER CONVERGE IS UNKNOWN
30
20
10
0
0
30+00
60+00
90+00
120+00
150+00
180+00
210+00
240+00
270+00
300+00
330+00
360+00
390+00
420+00
450+00
SECTION A - A
For the location of SECTION A-A see the DRAINAGE MAP
LEGENDS
SOILS
SILTY CLAY LOAM
SILT LOAM
CLAY
SUB-STRATUM
SILTSTONE
SANDSTONE
IRRIGATION DITCH
DRAINAGE DITCH
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
TYPICAL VALLEY X-SECTION

FIGURE 6



RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
CONDUCTIVITY TEST SITE MAP
As Shown
J.M. Shore

This area coincides with a saline ground water mound lying at a depth of approximately 1,968 feet in alluvial and non-marine sediments (Gupta, 1975).

The saline ground water mound is called connate water. An inland sea is believed to have been trapped during the Late Paleocene Period leaving a mound of connate water in the Kione Formation, Upper Cretaceous. This connate water, containing principally sodium and chloride, is thought to rise upwards along the Sutter Basin Fault under artesian pressure. The pressure is created by inflows of fresh water into the Kione sand formation at Sutter Buttes. The hydraulic head is estimated to be 262 to 426 feet (Tanji, 1975). Curtin's (1971) and Tanji's (1975) findings pointed to the major salt load in discharges at Karnak as being rising connate water, altered somewhat in cationic composition due to ion exchange.

To date, there has been no substantiated account of salt buildup in soils in this area of high TDS. To address the concern of salt buildup in soils, the University of California, Davis tested for saturation extract conductivities and chloride concentration at representative sites from 1971 to 1978. Eleven of the 32 regular sample sites were located in the delineated areas of high TDS in drain waters. Based on these analyses Henderson (1978) recommended discontinuance of sampling. Henderson stated that there was no trend in the salinity or chloride of sampled soils over the period 1971 to 1978.

A number of factors contribute to the lack of buildup of salts in the soils overlying the connate water. These factors include but are not necessarily limited to: 1) a siltstone at a depth of approximately 40 inches occurring in patches over the area, 2) leaching and drainage, and 3) clay soils overlying a sandstone.

The sandstone appears to be the most important of the preceding factors. The top of the sandstone has been encountered at depths of three to five feet in the east central portion of Sutter Basin and appears to be dipping southwest, being encountered at depths up to 10 feet in the southwest areas of Sutter Basin (Henderson, 1972). Tanji (Tanji, 1975) stated that this sandstone-like material readily conducts water and appears to act as a built-in underdrain. Henderson (Henderson, 1972) noted:

> "Typically, when a test hole is drilled, no water or obviously saturated soil is encountered until the "sandstone" is penetrated. Then the hole fills quickly and the water level rises well above the layer. A 2 1/2 inch diameter hole can be pumped with a small hand pump at a rate of 1 to 2 gpm but the water level drops only a short distance and recovers quickly when pumping stops. The flow is thus quite rapid."

Excavation of drainage ditches through this sandstone is the apparent cause of the high TDS area shown on Figure 2. This sandstone layer is probably truncated on the western edge of Sutter Basin. The cause of this truncation is past migration of the Sacramento River across ancient flood plains. Containment of the upward driven connate water by the sandstone would cause it to be found deeper in the western and southern portions of Sutter Basin.

Potential Salt Buildup

Inspection of soil maps and interviews with local experts revealed a potential for salt buildup in silt loam soils paralleling the Sacramento River levee. The pattern of the silt loam soils, mapped as saline-alkali soils in 1965 and/or saline sodic soils in 1988, suggest an old river channel under the present Sacramento River levee.

The 1915 Reconnaissance Soil Survey of the Sacramento Valley (Holmes, 1915) classified the preceding silt loams as excellent. This suggests that prior to the construction of a contiguous levee in the 1920s, salt buildup in these soils was practically non-existent. Frequent river overflows would have promoted the flushing of any salts that might have accumulated.

A 1965 Reconnaissance Soil Survey (Gowans, 1965) mapped an extensive band of saline-alkali soils. A 1988 Soil Survey of Sutter County (Lytle, 1988) mapped a smaller area of saline/sodic soils. Areas with past salt problems identified by Gordon Bailey (1995) are also shown on Figure 2.

The historical sequence suggests a hydraulic connection between the Sacramento River and the silt loam band inside the levee. The gradient between high river levels and the silt loam soils, established by construction of a contiguous levee in the 1920s, promotes upwelling of waters in the silt loam soils.

The implied reduction of saline soils from 1965 to 1988 suggests that a salt buildup can be managed by leaching and drainage. Evapotranspiration over time, without downward leaching, causes salts to build up. The amount of irrigation required to provide the desired leaching can be established. Land owners and operators appear to be applying ample irrigation at present to prevent salt buildup in the soils and apparently have leached formerly saline soils.

Rice as a crop insures prevention of salt buildup. In 1972 Henderson conducted a study of 20 rice fields to determine downward percolation of water. Seepage rates ranged from 0.1 to over 0.5 inches per day. Henderson stated: "Even the lowest rates would be more than adequate to wash out any previous accumulation of salts in the upper soil. There is little doubt that rice culture contributes to the control of salt accumulation in Sutter Basin soils" (Henderson, 1972).

Water Budget

To establish a water budget, the year 1993 was selected (see Table 4). The Company has records on the amount of water sold to each grower and the amount of acreage planted for the 1993 crop year. The acreage outside the Company service area was assumed to be the same crop pattern as the 1990 Department of Water Resources (DWR) land use maps. The rainfall record from the Tisdale pumping plant was used for the precipitation estimate of 22.14 inches. BOR water diversion records at the three Company pumping plants were used for pumped water from the Sacramento River of 184,532 acre-feet. Other BOR records, where they existed, were also used. BOR records show that the volume of water diverted from the Sacramento River by other BOR contractors is 26,034 acre-feet. There were areas where no records existed for actual water pumped from the river or wells. It was assumed that water from the entire area was either used for evapotranspiration (Et) or was lost to deep percolation or direct run off into the drainage net. The records show that the discharge at the Karnak pumping plant was 201,275 acre-feet for 1993.

Crop Et was estimated using CIMIS reference crop Et data from the Nichols station and appropriate crop coefficients. The cropland acreage, other land use data, and the Et estimates were combined to estimate the basin Et use of 224,537 acre-feet for 1993.

The greatest uncertainty exists in estimating the division of water from the ground water table into connate water discharged under artesian pressure and ground water discharged under the pressure associated with water surface elevations in the Sacramento River, Sutter Bypass, and the Feather River. The identified connate water area is drained by nine percent of the drainage system in the basin. If connate water discharge is related to this percentage of drainage system, then 7,300 acre-feet of ground water discharged at Karnak came from the connate ground water body (equivalent area influence). The remaining 73,000 acre-feet of ground water came from the area influenced by the river and bypass system. This estimate is the minimum reasonable amount of connate water possible. If the connate area is under greater hydraulic pressure in the basin, then the volume of connate water would be 29,200 acre-feet and the river and bypass system ground water volume would be 51,100 acre-feet (connate head four times larger). These two values represent a range of possible values for partitioning the ground water entering the basin from these sources. These values are shown in Table 4 and Figure 7.

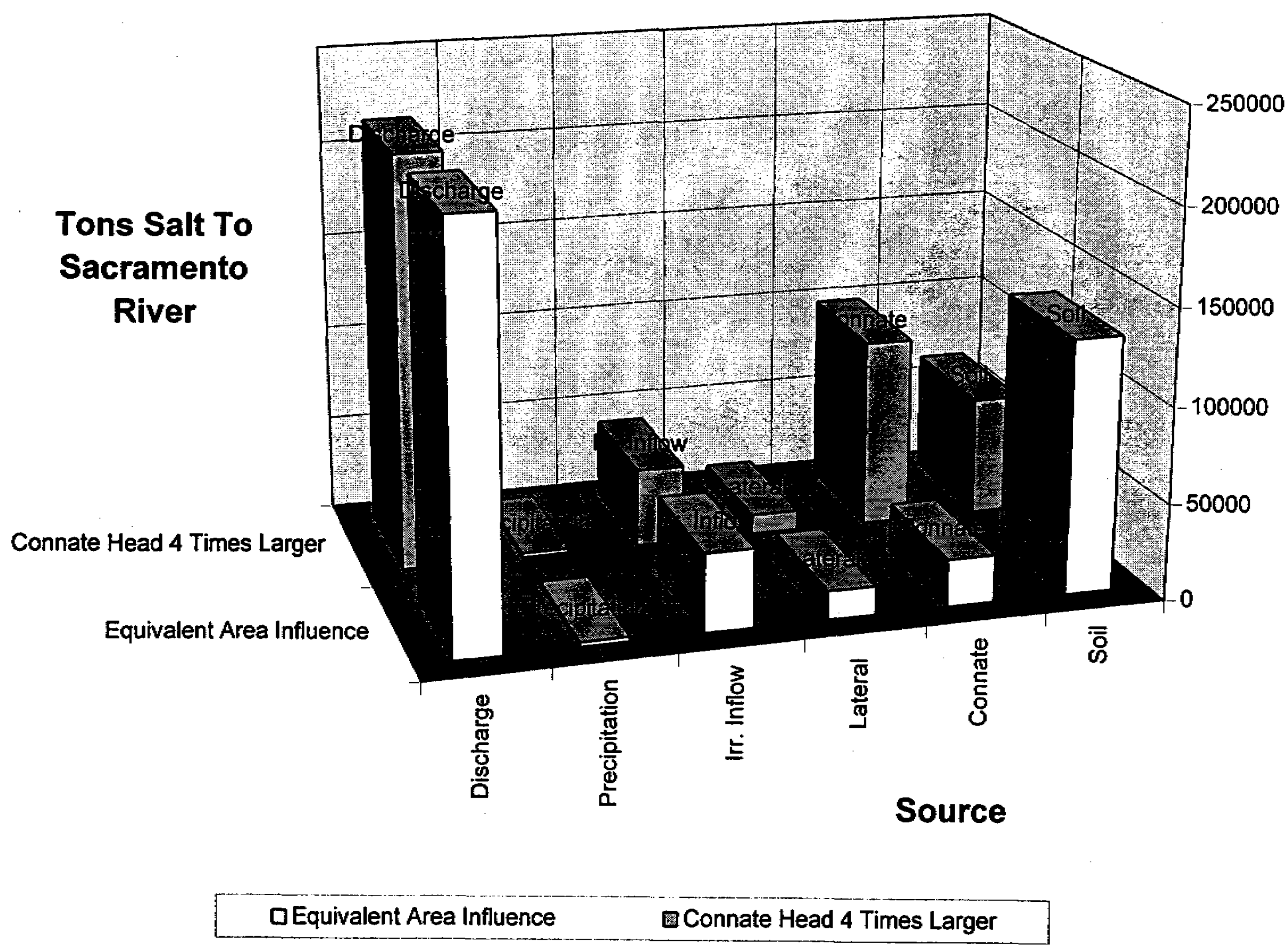
Table 4 - Water Budget

Based on 1993 Records

Water Source	Volume (acre-feet)
Rainfall (22.14 inches)	113,700
Company Diversions	184,500
BOR Diversions (Rimlands)*	26,000
Non-BOR Diversions (Rimlands)*	21,000
Estimated Lateral River Seepage	73,300
Estimated Connate Portion	7,300
TOTAL	425,800
Evapotranspiration (from 1/1 to 9/30)	176,100
Et (from 10/1 to 12/31)	48,400
Karnak Discharge	201,300
TOTAL	425,800

Note: "Rimlands" is the local terminology for non-Company areas.
These figures are based on 1993 records and do not reflect average or typical conditions.

Figure 7. Range of Salt Sources In Drainage District



There is no area in the basin which is not within 10 feet of the water table. Most areas are within five feet and some areas are within 18 inches. The water table is controlled by the drainage ditch system, Sacramento River elevations, elevation of water in the Sutter Bypass, the elevation of the Feather River, and artesian pressure in the "connate" water area. The entire basin is essentially a depression where the combination of river and irrigation ditch hydraulic head, drainage ditch water surface manipulation, precipitation, and irrigation water surface and deep losses control the Karnak outflow.

Salt Budget

Salt enters the basin by precipitation, ground water, soils, and river diversions. The river and bypass system ground water quality is quite good with an estimated 0.20 tons of salt per acre-foot. The connate water quality is distinctly different with an estimated 3.38 tons of salt per acre-foot.

The estimated salt discharge at Karnak in 1993 was 214,700 tons of salt. The salt brought into the basin from precipitation and irrigation diversions was 50,000 tons. Using the partitioning of ground water sources in Table 4, the connate salt was between 24,700 tons and 98,700 tons. Total salts from the ground water system were between 10,200 tons and 15,000 tons. The remaining salt must have come from soil sources and ranged between 55,800 and 125,000 tons. These ranges are shown in Figure 7.

Connate and rim waters were estimated to contribute about 40 percent of drain water outflow and roughly 20 percent of the salt outflow. This estimate of salt contribution from connate and rim waters is much smaller than the 70 percent estimated by Tanji (Tanji, 1975). The salt budget presented here implies that 58 percent of the salt load from this area to the Sacramento River is leached from the basin's soils. There is a lot of uncertainty in these estimates and more work should be done to characterize the area before significant modifications to the system are made.

SECTION IV

DESCRIPTION AND ANALYSIS OF WATER CONSERVATION MEASURES

As the January 10, 1995, "Draft Guidelines and Criteria for Water Conservation Plans" (Western states) by the BOR states: "Water conservation is not an end in itself. It is a means of achieving specific goals such as: saving money, higher crop yields, reduced soil erosion, reduced drainage problems, improved water supply and delivery reliability, or water supplies for additional use."

The Reclamation Reform Act and the Central Valley Project Improvement Act require that entities contracting for Federal water project water supplies develop water conservation plans. These plans need to examine existing water management practices, evaluate other water management strategies, and determine how to implement appropriate water conservation measures.

One of the most important components of the plan is to identify and evaluate water conservation measures. The BOR has identified 14 potential measures that should be evaluated for suitability in reaching the water conservation goals.

The measures should be evaluated based upon (A) applicability to the district, (B) technical feasibility, (C) the evaluation of legality under state/federal law, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts. The 14 measures identified by the BOR have a demonstrated record of effectiveness in reducing losses of, making more efficient use of, or otherwise conserving, water. Due to the lack of legal expertise in NRCS, item (C) will not be analyzed.

1. Incentive Pricing: Implement an increasing tiered block water pricing structure, or other water pricing structure, that promotes the efficiency of water use.

Block rate pricing could be used to motivate growers through price incentives to reduce the amount of irrigation water that is applied to the fields. A higher price for water applied in excess of what the crop requires could motivate growers to modify their operation to reduce water use. The concept is to encourage the irrigator to develop the best possible irrigation system and management practices in order to minimize the need to purchase the more expensive, or tiered, irrigation water. This price incentive mechanism can have a significant positive impact on irrigation water use while having minimal impact on the total farm-level expenditure on water.

Although growers are motivated by many factors such as risk, irrigation management, requirements for proper crop rotation, employee skills, and other factors, the economic principle of profit maximization plays a key part in explaining the effect that tiered water pricing could have on water conservation. Profit maximization is based on the belief that businesses respond to input and output prices. Raise the price of a key input used in a business and the owner either cuts back production, switches to a substitute input, or changes the goods produced.

In the case of a farm operation the full response depends on feasible crop rotations, land quality, grower's responsiveness to irrigation water prices such as do they cut back a little or a lot, the substitutability of fertilizer or other inputs for irrigation water, the magnitude of water price increase, irrigation water expense as a share of total crop budget, and other factors. A full study of these factors, such as one carried out with economic models, would give a better understanding of how tiered pricing would affect this irrigation district and its growers.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Calculation of the water conservation savings that could be anticipated by the District from raising irrigation water prices is difficult. As mentioned in the previous paragraphs, a wide number of factors influence how growers will respond to price increases.

The actual setting of prices needed to carry this out can be done in a number of ways. Perhaps the most practical is to talk to irrigation district managers that have used tiered pricing and draw from their experiences. Trial and error may be needed to find the rates that meet the objectives of the District and its customers. Any approach to establish tiered pricing must include technological standards such as what is the minimum amount of water required to produce a particular crop.

In this region, another factor that must be seriously considered is how water price changes might limit the growers to rotate crops. For example, in some locations in the Sutter Basin growers will use rice in their crop rotation specifically to manage the salts in the soil. To successfully manage the salts a significant amount of water may need to be applied. An outside viewer of this may mistakenly presume that excess water is being applied.

Tiered pricing has been used by other purveyors. The Broadview Water District implemented a program to encourage a reduction in drain water. It should be noted that the Broadview Water District, in the San Joaquin Valley, is located in a different area than Reclamation District 1500 and the main concern was to minimize drainage from agriculture rather than to achieve a salt balance in the area. It is referenced in this document to show the types of effects that tiered pricing has had in a real world, though different, situation.

Present Conditions:

In 1993 the Company separated charges between a flat maintenance charge of $13 per acre per year plus a charge of $8 per acre-foot for water purchased. The annual maintenance charge is received from 50,083 acres, whereas the water cost is based on the actual amount of water purchased for the different crops.

Factors Considered:

A. This measure is applicable to the area.

B. The Company would need to determine the appropriate tiered price and gain the support of the landowners. To set the tier for which irrigation water would be priced higher, an analysis of the characteristics of the basin would be necessary. Typically, this would require a determination of the water needs of each crop for the various soils on which they are grown and adding some flexibility to account for other variations. An inherent requirement for incentive pricing to be effective is that growers have technically viable actions to take, such as a change in equipment or management practices, that will allow them to reduce the amount of irrigation water used for that particular crop.

For instance, tomatoes grown in this area generally require 2.38 acre-feet of water. A tiered price for water for this crop could logically be set slightly above this required level of water. The same logic could be used to establish the point at which the additional water purchases would be more expensive.

Currently, crops in the basin require consumptive use water in the range of 0.66 to 3.33 acre-feet/acre. In fact, in 1993 only 26 percent of growers were applying significant amounts of water above the crop needs. Therefore, only a small proportion of the growers might be responsive to tiered water costs and a higher water cost might elicit a relatively minor reduction in applied water.

D. Presently a specific price incentive program in the Sutter Basin to encourage greater water conservation is not in place. It should be pointed out that the current water pricing schedule does not encourage excessive water usage either.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

A complete analysis of the financial consequences of implementing tiered pricing was not possible in this study. However, an example of potential economic impacts is presented. Two scenarios are given in Tables 5 and 6; 1) growers do not adjust water applications with increased water cost, and 2) growers completely adjust water application with the increase in water cost. In this example it is assumed that irrigation water purchases above the requirements of each crop will be priced at $30 per acre foot. This price per acre-foot was selected to demonstrate the economic change depending on how growers respond to the increase in water cost.

For this example the current price of $9 per acre-foot of water is used and therefore the typical irrigation water purchase cost for each crop is: tomatoes, at 2.38 acre-feet, averages $21.42; rice, at 6.33 acre-feet, averages $56.97; melons, at 0.66 acre-feet, averages $5.94; and beans, at 2.43 acre-feet, averages $21.87. Only a few of the major crops were included in this analysis.

Table 5 (Scenario 1) shows the economic impacts when all growers who are over applying do not reduce irrigation water application to a level at or below when the $30 tiered price kicks in (inelastic response).

Table 6 (Scenario 2) shows the economic impacts when all growers who are currently over applying reduce irrigation water application enough to avoid increased water costs (tiered price $30).

The actual impacts of tiered water pricing in Sutter Basin would fall somewhere between these two scenarios. Clearly, some growers would accept some additional water costs and continue to apply water above the tiered level based on their specific conditions such as the need to manage the salts in the soil; others would adjust their water purchases downward. They would be more likely to reduce water application if the conservation practices and/or management changes are perceived to be less expensive than the added water cost. The Company would also face some revenue impacts depending on the growers' response to tiered pricing. Administrative expenses associated with implementing the tiered price program would also be incurred; however, this might be offset by the reduced purchase of river water and pumping costs.

This limited analysis shows the total quantity of water that could be conserved by price incentives is relatively small, though it appears to be an economically viable option to be considered.

The Broadview Water District, in the San Joaquin Valley, found some significant reduction in drain water using incentive pricing. Their use of incentive pricing was for drainage control, as opposed to water conservation. The goal set was to reduce the average amount of water applied by the growers by 10 percent. The existing base price of water was $16 per acre foot. Average water application rates were determined for each crop. Water application levels of 10 percent less were identified and the amount of water used above this level was priced at $40 per acre foot. This pricing program in 1989 resulted in the application of water on melons to drop an average eight percent.

E. & F. The present on-farm overall irrigation efficiency for the major row crops of tomatoes, melons, and beans exceeds 100 percent because part of the water requirement is met by the shallow water table. Beans are the lowest with 69 percent and melons are the highest. Data is available for 136 non-rice growers farming a total of 42,000 acres of cropland. These growers represent 75 percent of the total growers in the area. Assuming a target efficiency of 80 percent, 33 growers have irrigation efficiencies less than this. The amount of irrigation water reduction required for these growers to achieve the target irrigation efficiency is 2,700 acre-feet. Assuming these numbers are representative of the entire area, the total area-wide irrigation water reduction would be 3,600 acre-feet. This is less than two percent of the total water use. Some water savings , approximately 7,800 acre-feet, associated with rice production may also be possible. However, given the irrigation method currently employed the feasibility to reduce water usage further without significant crop impacts is much less likely.

Table 5: Impacts If Growers Continue To Apply Excess Water After Tiered Pricing Is Implemented.

CROP	ESTIMATED NUMBER OF FIELDS RECEIVING EXCESS IRRIGATION WATER	ESTIMATED NUMBER OF ACRES RECEIVING EXCESS IRRIGATION WATER (acres)	ESTIMATED AMOUNT OF EXCESS IRRIGATION WATER APPLIED **** Total (acre-feet)	Avg. per Acre (acre-feet/acre)	EXAMPLE TIER PRICE FOR EXCESS WATER APPLIED ($/acre-feet)	ADDITIONAL WATER COST TO GROWER WITH TIERED PRICE ($/acre)	TOTAL ADDITIONAL WATER COST FOR ALL ACRES WITH EXCESS IRRIGATION WATER APPLIED ($/crop)
Tomatoes	22	1,566	1,340	0.86	$30	$18	$28,190
Rice *	33	3,000	7,800	2.60	$30	$54.60	$163,800
Beans	11	1,135	1,080	0.95	$30	$19.88	$22,680
Melons **	-	-	-	-	-	-	-
TOTAL	66	5,701	10,220				$214,670 ***

* A significant proportion of these rice growers may not be using more water than required for their particular soil on which the rice is grown.

** Melon growers have generally been successful at utilizing the water table to supplement their irrigations, therefore there is no excess irrigation water applied.

*** This is also an estimate of additional revenue that the Irrigation Company would receive if growers continued to apply the same amount of water with tiered pricing implemented.

**** Only the major water using crops grown in the basin were included in this estimate.

Table 6: Impacts If Growers Respond To Tiered Pricing By Reducing Irrigation Water Application To Just Below Level Where Increased Water Cost Would Start to Be Incurred.

CROP	ESTIMATED NUMBER OF FIELDS RECEIVING EXCESS IRRIGATION WATER	ESTIMATED NUMBER OF ACRES RECEIVING EXCESS IRRIGATION WATER (acres)	ESTIMATED AMOUNT OF EXCESS IRRIGATION WATER APPLIED ***** Total (acre-feet)	Avg. per Acre (acre-feet/acre)	EXAMPLE TIER PRICE FOR EXCESS WATER APPLIED	REDUCED WATER COST TO GROWER WITH TIERED PRICE ($/acre)	TOTAL REDUCED WATER COST FOR ALL ACRES WITH EXCESS IRRIGATION WATER APPLIED *** ($/crop)
Tomatoes	22	1,566	1,340	0.86	$30	$7.75	$12,136
Rice *	33	3,000	7,800	2.60	$30	$23.4	$70,200
Beans	11	1,135	1,080	0.95	$30	$8.55	$9,704
Melons **	-	-	-	-	-	-	-
TOTAL	66	5,701	10,220				$92,040 ****

* A significant proportion of these rice growers may not be using more water than required, for their particular soil on which the rice is grown.

** Melon growers have generally been successful at utilizing the water table to supplement their irrigations, therefore there is no excess irrigation water applied.

*** This estimate does not include possible added grower costs such as equipment and/or management in order to reduce water application.

**** This is also an estimate of the loss in revenue to the irrigation company if growers eliminated over-application of irrigation water.

***** Only the major water using crops grown in the basin were included in the estimate.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

The amount of drain water reuse that currently takes place in the basin would no longer be possible. The volume of water discharged at Karnak and/or the volume available for reuse would be reduced by 3,600 acre-feet. This would result in a corresponding but unknown change in water quality in the area and the discharge to the river.

G. There may be several potential environmental effects. If the Company could reduce the amount of water diverted from the Sacramento River, they could avoid any thermal impacts that may be associated with routing the water through the area before it is returned to the River. Some riparian habitat may be lost. There is some potential of increasing the concentration of natural salts in the basin due to the combination of reduced irrigation and the connate ground water source. The drainwater that continues to be returned to the Sacramento River may involve higher concentrations of salts for this reason. A loss of water bird habitat is also expected if the rice acreage is reduced.

Analysis of This Measure:

Rice agriculture in the study area is basically the maintenance of a surface water table in the rice check. If the system has a tailwater return system or is a closed system, then the amount of water use is dependent on the Et of the crop and the permeability of the soil. Neither of these two factors is changeable by management or system design. While water use could be reduced by changing crops, this is not the intent of the measure. The deep percolation losses from rice in the basin can be considered constant for the irrigation season once equilibrium conditions exist.

If implemented, this measure would demand of growers very detailed and extremely accurate record keeping and water measurement.

2. <u>On-Farm Program Incentives</u>: Facilitate and/or provide financial incentives and assistance for on-farm water use efficiency improvements (e.g. lease, low interest loans, or water charge rebates for on-farm conservation measures).

Present Conditions:

The District currently has no programs in place to do this.

Description of Action:

Any incentive program will require some funding mechanism. These funds could come from a flat price increase in water costs, block pricing funds, or other funding sources. The funding sources could be used to fund on-farm efficiency improvements.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible. On-farm improvements may include structural and management measures. Irrigation water management, sprinkler systems, and tailwater return systems are examples of potential on-farm improvements.

D. The District would be required to determine and then manage a source of financial funds for such programs. This would result in some added expense that would need to be passed on to the growers through water costs. While management measures on some farms could be inexpensive, system improvements could be in excess of $50 per acre.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

When considering educational and technical assistance for water conservation, the typical costs for on-farm water management for irrigation consultants is about $5 per irrigated-acre. Using this cost, targeting 2,700 acres per year, and a farm visit every five years, the cost for assistance would be $2,700 per year. The targeted areas would be bean and cropland where excess water is applied. The typical success rate would be a water use reduction of about 10 percent of the excess water. With 2,400 acre-feet of excess water applied, this would be a reduction of 240 acre-feet per year, at a cost of $12 per acre-foot.

E. Presently, the rice lands have tailwater return or closed systems so irrigation efficiency improvements would be minimal. The remaining 47,000 acres could be eligible for this type of assistance. There would only be 12,000 acres which could be improved to 80 percent. The remainder of the area is above 80 percent. Systems operate efficiently only when the proper management is present.

F. Approximately 3,600 acre-feet of water would not be ordered from Shasta in this situation as discussed in the Incentive Pricing section previously. This is less than three percent of the total water use in the District. The estimate for water savings for rice is unquantified and it is assumed the rice growers are currently fairly efficient.

Depending on the effectiveness of the on-farm water conservation incentives, available drain water for reuse may be limited, requiring some growers to purchase additional District water.

G. The environmental effects of reduced irrigation water used would be the same as discussed in the Incentive Pricing section.

3. <u>Drought/Water Shortage Contingency Plan</u>: Develop a drought/water shortage contingency plan for the district that outlines the policies and procedures for operation and allocation during water supply shortages.

Present Conditions:

At the beginning of the irrigation season the BOR tells its contractors how much water is available for that year. In short water years the Company may allocate this water to its customers by crop in accordance with the Reclamation Reform Act of 1986. In 1992, the contracted amount was reduced by 25 percent. The Company does have a mechanism in place to deal with drought/water shortage situations.

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. This measure is economically feasible.

E. Unknown.

F. Unknown.

G. Unknown.

4. <u>Water Transfers</u>: Facilitate voluntary transfers that do not unreasonably affect the district, the environment, or third parties.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Present conditions:

The Company is currently exploring water transfer opportunities. The Company owns the water rights to the water and is the contractor with the BOR. The water rights are enjoyed mutually by landowners and not as individuals. The impacts of transfers on the Company, the environment, or third parties need to be examined.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. There is the potential for individual landowners and/or the Company to receive additional financial resources that could supplement income as well as reduce per acre irrigation water cost. However, the local economy may be negatively impacted. Fewer agricultural inputs and crop processing services may impact the business community.

E. Probably none.

F. Probably none.

G. There may be problems due to additional salt buildup in the soil due to reduced irrigation applications.

5. <u>Conjunctive Use</u>: Increase conjunctive use of surface and ground water within the district, begin working with appropriate entities to develop a ground water management plan.

Present Conditions:

In 1993, 201,300 acre-feet of water was returned to the Sacramento River. However, 95,400 acre-feet of this water is rainfall in the winter or lateral flows to the drainage net and cannot be captured for uses during the irrigation season.

Of the 105,000 acre-feet of water which leaves the area during the irrigation season, several questions need to be answered before a commitment to full or partial use is made. The questions are: what is the distribution of salinity in the basin and how much water is available in those areas which have suitable water quality?

For the purposes of this report, it was assumed that approximately 50 percent of the 105,000 acre-feet, or a total of 52,500 acre-feet, of this water could be recirculated based on available 1993 data.

An unknown volume of freshwater underlies the basin. Although the sources of recharge have not been quantified, the Sacramento River is thought to be a major source and is, therefore, not a legitimate source of new water. The ground water in the lower section of the basin is generally not suitable for irrigation use due to the effects of the connate water. Tapping of ground water should be discouraged until sufficient data exists to allocate withdrawals that will not create adverse impacts.

The ground water table in the area is generally five feet under the surface. During the irrigation season it can be brought to less than 18 inches below the surface by manipulating the water level in the drainage ditches. This can be considered a form of conjunctive use.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Factors Considered:

A. This measure is not applicable to the area due to the high water table and saline conditions of the ground water.

B. This measure is not technically feasible in the service area. Another area would need to be found in which to store water underground.

D. Because storing ground water in the basin is not an option, the Company would need to cover the cost of the infrastructure required to transport the water to another district, pump the water from the ground, and transport the water back to the area when it is needed. Some administrative expense would also be incurred to monitor the quality of the increased amount of reused water. While the Company would reduce pumping costs for water pumped from the Sacramento River, the cost of pumping water from the ground with a lift of 50 feet and transporting the water to and from another area would surpass this cost and costs would actually increase.

E. Not applicable to this area due to the lack of technical feasibility.

F. Not applicable to this area due to the lack of technical feasibility.

G. The Company could possibly reduce the amount of water diverted from the Sacramento River but this is offset by the reduction of water discharged back into the River. It is unlikely that water could be stored in the service area's ground water basin due the detrimental crop and wildlife effects the increase in salinity would create.

Analysis of This Measure:

The basin is underlain by water that is too saline for agricultural use. It is likely that all of the area is underlain by saline water at some depth. The largest quantity of shallow saline water is associated with the underground connate water. An unknown volume of usable water is also present. Most of the usable water has been found along the western half of the basin and very likely has a direct hydraulic link to the river system. The District presently manipulates the ground water table by adjusting the water level in the drain ditches which does increase conjunctive use by crops, particularly those adjacent to the rice fields.

Conjunctive use usually implies the storage of water in the ground water basin during years of excess supply and use of the stored water during drought years. This only works when there is no direct link between the ground water and surface water sources. The Company would need to identify an area outside the district with suitable hydrogeologic characteristics, contract for storage, and then find a method for delivery to and from this area.

6. Land Management: Facilitate alternative uses for lands with exceptionally high water duties, or whose irrigation contributes to significant problems (e.g. drainage that does not meet discharge standards).

Present Conditions:

There are no lands which have high water duties or problems. The connate water salinity is a function of geology, not irrigation. Present land management practices, cultivation, and irrigation water management are done in a manner that minimizes problems that relate to water discharges which exceed standards. Rice, which has the potential to contribute to degradation of water quality and exceed water quality standards, is being grown and managed in closed systems. Rotations in which rice, tomatoes, melons, grain, and safflower are being grown are managed efficiently. Problems associated with

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

irrigated crops are seepage from fields into drains and the timing of drainage amongst neighboring growers. In most all cases, drainage discharge standards are not being exceeded.

In the high salinity areas irrigation has actually helped to make the land more viable for agriculture.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. Financially, feasibility is limited due to the lack of other income-producing uses for the land. Financial compensation would need to be found for landowners putting land out in retirement.

E. This measure would not change water use efficiency in this area.

F. If land was taken out of production, some water would be saved since it would no longer be needed for irrigation.

G. There would be salt buildup in the soils of the area, leading to an overall decrease in suitable habitat for the current species found in the area.

7. Operational Practices and Procedures: Evaluate potential district operational policy and institutional changes that could allow more flexibility in water delivery and carry over storage.

Present Conditions:

Company policy states that irrigation water delivery to growers requires a 48 hour advance notice and a 12 hour advance notice for shut off. The current system is effectively an on-demand schedule. The Company advises the BOR of estimated water needs on Monday for one week. The area is divided into six service areas with six ditch riders working together to achieve flexibility in delivery and service. Present policy allows ditch tenders to shut gates where water is obviously being wasted.

Factors Considered:

A. This measure is applicable to the area.

B. This measure may not be technically feasible without a regulating reservoir due to the time required to allow water from Shasta Dam to reach the area.

D. There would be cost associated with hiring more District personnel to be available for water delivery and shut-off. There would also be additional cost associated with the installation of additional water management equipment.

E. There would be more flexibility in water delivery, though not necessarily an increase in water use efficiency.

F. There would be a certain amount of water saved if landowners had more flexible delivery and shut-off.

G. There would be less water in the ditches and canals, reducing water edge habitat.

Analysis of This Measure:

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

The existing delivery system is fairly flexible. If the District increases the use of drainage water, it could order less and/or assign this water to carry-over storage. This assignment to carry over storage is especially desirable due to BOR costs assigned to full delivery of contract water. This carry over water would have to be stored in other ground water basins and "traded" or sold during drought years. If there is a lack of capacity for flood storage, this carry-over water would be released and lost downstream.

8. Irrigation System Scheduling: Implement a program of distribution system scheduling based on area wide crop demand modeling or advanced demand requirements.

Present Conditions:

The responsibility of ordering water belongs to the grower.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. There would be additional costs associated with hiring more District personnel to implement the program and the installation of water management equipment.

E. There would be some improved efficiency of water use on the least efficient acres irrigated as mentioned previously in the Incentive Pricing section. However, this is only three percent of the total water use in the District.

F. As mentioned previously, 3,600 acre-feet could be saved by increasing the least efficient growers' efficiency to 80 percent. The assumption is made that, if growers are informed how much water they are using in comparison to other growers, they may see how they can also reduce their own water use.

G. Care must be taken not to reduce irrigation levels below the amount needed to continue leaching the salts from the soil. Saline soil would affect existing habitats and land uses.

Analysis of This Measure:

Computer models could be used with the crop acreage figures, planting dates, and other information to check or anticipate water orders. The Company would assume considerable risk if it took over water ordering responsibility from the growers. The information could be used to identify growers who could use assistance in increasing water use efficiency. Flexibility could also be increased by better drainage water quality assessments and storage/yield estimation. If the Company knew the "typical" flows and quality from the drainage laterals, it could adjust its orders to use this water.

9. On-Farm Scheduling: Facilitate the delivery of crop water use and on-farm delivery information to district customers for on-farm irrigation scheduling.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Present Conditions:

Presently, growers in the area have access to CIMIS data and the AGWATER programs. These programs need to be used with caution in high water table areas such as the Sutter Basin.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. There would be cost associated with hiring personnel to provide landowners with education, information, and technical opportunities.

E. There would be some improved efficiency of water use on the least efficient acres irrigated as mentioned previously in the Incentive Pricing section. However, this is only three percent of the total water use in the District.

F. As mentioned previously, 3,600 acre-feet could be saved by increasing these growers to an efficiency of 80 percent.

G. Care must be taken to irrigate often enough and with enough water to continue the leaching of the salts through the soil. Saline soil would affect the existing habitats and land uses.

Analysis of Measure:

The Company could become more involved with training and information transfer of irrigation information and technology. For instance, the Company has available the typical water use for each crop and distribution of water orders in the area, so growers could compare their use to that of other growers. This information is already being distributed in bills.

10. Pump Efficiency Evaluations: Coordinate the evaluation of district and private pumps with local utilities, evaluating both energy and water efficiency.

Present Conditions:

Currently the Company supports PG&E's pump testing program.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible.

D. This measure could increase energy and water cost savings, but there would be some expense associated with equipment and personnel costs for monitoring.

E. Water efficiency would increase with properly functioning pumps.

F. Some water would be saved if efficiencies increased.

G. There would probably be negligible effect on the environment.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

11. Distribution Control: Modify distribution facilities and controls to increase the flexibility of water deliveries (e.g. automate canal structures, institute variable turn off times, etc.).

Present Conditions:

The ditch riders are presently allowed to close or reduce delivery to customers who are spilling water from their fields. Growers are charged for what is ordered, whether it is used or spilled.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is not technically feasible without a regulating reservoir for storage. If the District adheres strictly to policy to order water two days in advance, this limits the opportunities to increase flexibility of distribution. If such an option was feasible, however, there would be more delivery and use flexibility for the individual grower.

D. There would be almost $5.7 million in costs involved with automating equipment and hiring additional personnel.

E. If the two-day advance limitation is adhered to, there would be no significant increase in water delivery efficiency without a regulating reservoir.

F. For the same reason, no significant water would be saved.

G. There would be no significant environmental changes with this measure.

Analysis of This Measure:

In 1993, the Company charged its customers for 143,000 acre-feet of water. Rice used 107,000 acre-feet of water, generally with closed or tailwater return systems. The assumption that 30 percent of the remaining 36,000 acre-feet could be spilled leaves 10,800 acre-feet. Control gates to spill this water into the Sacramento River or a regulating reservoir would cost $4,700,000 while the reservoir would add an additional $1 million in costs. The annual cost for these gates at eight percent interest with a 50-year life would be $384,000. If the "saved" water was spilled back into the Sacramento River, the difference in water use would be dependent on where the water returns to the River. There may be some thermal changes in the returned water.

12. Reuse Systems: Construct district operational spill reuse systems.

Present Conditions:

Currently, rice growers operate closed basin or tailwater return irrigation systems rather than flow through systems, so there is no opportunity to improve irrigation water use on these lands. The remaining crop land could incorporate a tailwater return system that could improve the on-farm irrigation water use efficiencies.

The Company presently reuses up to 15,000 to 16,000 acre-feet per year using its facilities. There is also an estimated 15,000 to 16,000 acre-feet used by growers who pump from the drainage system. These figures total 30,000 to 32,000 acre-feet and are based on 1994 records. Some growers operate on-farm reuse systems.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Potential Basin-Wide Recirculation System

A recirculation system to move drainage and tail water upslope to the main canal would lift additional water from Bohannon Dam (mile 8.2) at mile 7.5 to the canal at mile 19.5. There are several design constraints for this system: (1) recirculation at this scale may not be possible given the salinity of the system; (2) the present invert of the ditch should remain the same; (3) the maximum water surface should be four feet below the ground surface; (4) the water surface should never be higher than elevation 14 at Karnak; (5) velocities in the ditch system should be nonerosive.

The volume discharged from Karnak during the 1994 irrigation season was 71,000 acre-feet. The District estimates that 80 percent of the drainage water in the service area is generated upstream of Bohannon Dam. If the system is designed to recirculate this water back to the main canal, this would contribute an additional 320 cfs that would be available for recirculation.

If the discharge record for 1993 is used to estimate the amount of water which could have been recirculated in the system, the total volume recirculated would be 24,655 acre-feet for July and August of 1993. The average discharge from Karnak would have been 50 cfs or 6,149 acre-feet. The drainage discharge to the Sacramento River during July and August would have averaged an EC of 2,263 micromhos/cm for July and 2,215 micromhos/cm for August if the salt content remained constant. It is more likely, however, that salt would be stored in the soil profile during the irrigation season. Downstream water users would have had to find another source of water to replace the water the District was no longer discharging.

Currently, the EC of the drainage water at Karnak during the initial portion of the irrigation season is less than the EC during the winter due to the dilution effect of the additional irrigation water. The EC eventually stabilizes between 400 and 750 micromhos/cm. If more water were recirculated in the basin, this would change dramatically and an even higher winter EC would become more typical. Instead of the dilution of the salts occurring in summer, the salts would build up and not be flushed out until winter, creating a higher winter EC than usual. In order to maintain productivity, the salts accumulating in the soil need to be removed by leaching. It does not matter what the source of these salts is: agricultural productivity is damaged if the salts are not properly managed.

An analysis of the impacts from recirculating water in the basin was done using EC data from July and August 1990 to 1993 and Karnak discharge data to develop a regression equation for discharge at Karnak versus EC of the drainage water. The R-squared value was 47 percent for the unculled data set and 66 percent for the data set with four points removed. It also appears that if more water is recirculated the intercept changes. The intercept for the four points which were dropped was 810 with a nearly identical slope.

The results of this study show that in 1994, a low water year, the soils of the total basin stored an additional 1,100 tons of salt during the irrigation season. Recirculation efforts were maximized due to the low water supply.

If a recirculation system was built to bring eighty percent of the remaining 1994 drainage water back to the company supply system, the increase in soil salinity would be 48,000 tons of salt. The estimated mean discharge EC at Karnak would increase to between 790 and 810 micromhos/cm for the months of April through September.

The additional salt would need to be leached from the system by precipitation or additional water at some future date to maintain long term productivity. A more detailed analysis of the relationships between Karnak discharge, amount diverted, Et, EC, recirculation, and precipitation needs to be developed in order to reduce risk and uncertainty which would be associated with the installation of a basin-wide recalculation system.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible to the area.

D. The Company would need to gain the support of the landowners and provide appropriate incentives to implement a significant modification to the way growers manage their farming operation. Growers would be faced with some additional costs. The typical installation cost of a tailwater return system is $200 per acre and the operation and maintenance (O&M) cost is $10 per acre. The average annual cost is estimated to be $30 per acre for an on-farm system.

For a basin-wide system, the canal upstream of station 540+00 (mile 10.2 or 2 miles north of the dam) would need to be widened to 46 feet to the main canal. This would require the excavation of 459,500 cubic yards of material. The pumping plant would consist of four groups of three 100 cfs propeller or axial flow 300 horsepower pumps (Model 52 pmr 505 RPM @ $90,000 for the pump and $39,000 for each motor). The cost of the three pumphouses was estimated at $50,000 each. The Bohannon Dam plant would be optional and was not used for the cost estimate. There would be no requirement for storage reservoirs because the ditch could store 431 acre-feet of water. An additional 510 acre-feet would be stored below elevation 14 from Bohannon Dam to the Karnak pumping plant. The cost of the pumps was obtained from Byron Jacobs Company in Chico (916-342-3551). The estimated excavation and disposal cost of the material is $2 per cubic yard. The design life of the system is 25 years. Maintenance of the plant is restricted to embankments and pumps because the drainage system costs are presently taken care of by Reclamation District 1500. Installation costs would be approximately $2,500,000. The estimated maintenance cost is estimated to be five percent of installation costs. Power costs would be approximately $7 per acre-foot.

If the installation and maintenance costs are distributed over the service area of 62,500 acres and amortized for 25 years at eight percent interest, the annual per acre cost of installation and maintenance is $5.50 per acre. The power cost for lifting the water back to the main canal is about four times the cost for lifting the water from the Sacramento River.

E. The efficiency of water use or delivery would not significantly change.

F. There were 105,000 acre-feet discharged to the Sacramento River during the 1993 irrigation season. The year 1993 was a high water year for the river and contractors received 100 percent of their allocations. The Company did not have a recapture program in 1993 though some of the landowners recaptured water on their own. For evaluation purposes, assuming that 50 percent of this water could be available for reuse, 52,500 acre-feet could be incorporated into the reuse program during the irrigation season only. This assumption is based on the amount of water lost in the irrigation ditches, the volume of deep percolation losses from rice fields, and the estimate of lateral-flow water from the river during the irrigation season. These three sources of water are known to be of good quality. The quality is degraded by salt concentration from evaporation, remnant salts in the soil profile, and connate water.

In a short water year, such as 1994, where allocations are cut by 25 percent, the District would tend to reuse the same amount of water available as in 1994, or 15,000 to 16,000 acre-feet per year, with an additional 15,000 to 16,000 acre-feet being reused by individual growers. The amount available for reuse will vary widely from year to year and will depend on the quality and quantity of the drain water.

This system would decrease flows in the Sacramento River below Karnak by 270 cfs for a water year similar to 1993. This would mean less water available for recapture and reuse. The Company could also have reduced the diversions from the Sacramento River to 108,000 acre-feet if all possible reuse had taken place.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

G. There is some potential of increasing the concentration of natural salts in the basin due to the connate ground water source and less freshwater for leaching. The reduced amount of drain water that would continue to be returned to the Sacramento River may involve higher concentrations of salts. Less water would be ordered and/or discharged to the river, reducing the amount of water in the river downstream.

Growers would need to closely monitor the quality of the water they are applying. This may result in a level of uneasiness in the growers until this higher level of water reuse is proven in the field to not significantly reduce crop productivity.

To maintain high water quality all reused water should follow the standard of a maximum EC of 750 micromhos/cm.

Analysis of This Measure:

Between the Company's reuse system and private individuals reusing water, an estimated total of 30,000 to 32,000 acre-feet was reused in 1994. There is the potential for more water to be reused but currently as much water as the system allows is being used. To increase the amount of reused water would require costs for the installation of an upgraded system. It is also only an assumption that the water will be of high enough quality to be reused. Sometimes there is the need to mix fresh water with the water available for reuse to maintain an EC of 750 micromhos/cm.

13. Distribution System Lining: Line distribution ditches and canals or convert to pipe.

Conversion to Lined Ditch

Present Conditions:

Two ditch lining options were identified and evaluated (see Figure 8). One option considers lining approximately 34.4 miles of the 167 miles of the unlined irrigation water distribution ditches in the service area while the second option considers the lining of 5.0 miles of ditch. The ditches that were evaluated to be lined with concrete are the segments for which the soils allow excessive amounts of irrigation water to seep into the ground water. In 1993, the Company diverted approximately 185,000 acre-feet of water from the Sacramento River using three pumping plants. Approximately 42,000 acre-feet per year of this water was not used for irrigation due to evaporation, seepage in the drainage system, and return flows to the Sacramento River. The lining of the ditches would prevent some of this water seepage.

There are 167 miles of distribution ditches in the service area. These ditches vary in depth and cross section. The loss associated with an irrigation ditch is a function of the soil, the wetted perimeter, and the height of the water surface over the mean ground water table. The Soil Survey was used to obtain the unified classification for the soil; the Civil Engineer's Standard Desk Reference was used to estimate the k factor, or coefficient of permeability, associated with the soil classification; and the Company's ditch map and soils maps were overlaid to obtain reach lengths of each soil type. Typical ditch dimensions were obtained from an interview with the Company Field Manager. The average head was obtained by matching the estimated ditch loss for the study area during the 1993 irrigation season to the obtained ditch characteristics.

Concrete lining was assumed at a cost of $150 per cubic yard. The k factor for concrete is about twice the k for a CH soil (0.0000001 versus 0.00000005). This means that some soils would not benefit from the installation of a lining material. These soils were not considered for lining.

Factors Considered:

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

A. This measure is applicable to the area.

B. This measure is technically feasible for only some of the ditches in the service area. Only the ditch segments where the soil allows for large amounts of water seepage were considered for lining.

Maintenance of the lined segments would require replacement every 10 years.

D. Lining 34.4 miles would cost $12.8 million, while lining 5.0 miles would cost $2.3 million. The average annual costs, based on 10 years, would be $1,852,000 for 34.4 miles of lining and $337,000 for 5.0 miles of lining. The average annual cost per acre-foot of water prevented from seeping is $50 for 34.4 miles of lining. This is over five times the current per acre-foot cost that the water user pays the Company. For 5.0 miles of lining, the average annual cost per acre-foot of water prevented from seeping is $17. This is about twice the current per acre-foot cost that the water user pays the Company.

The Company would need to cover the costs of installation and maintenance through landowner fees. Currently the cost to the landowner is $14.50 per acre per year. For 34.4 miles of lining, the added cost would raise the annual fee for the assessed gross acres of 50,083 by $37 per acre per year. For 5.0 miles of lining the added cost would be about $7 per acre per year.

The Company could reduce some pumping costs because less water would need to be diverted from the Sacramento River. This could amount to $65,000, or $1.30 per gross acre, saved for 34.3 miles of lining and $21,200, or $0.42 per gross acre, for 5.0 miles of lining with an assumed pumping cost of $1.75 per acre-foot.

Landowners would not be required to modify their current farming operation.

E. There would be no significant improved efficiency of on-farm water use or delivery. The Company would have increased efficiency of water delivery.

F. The amount of water lost to seepage would be reduced by 37,100 acre-feet per year for 34.4 miles of lining and 19,700 acre-feet per year for 5.0 miles of lining.

G. Lining would eliminate the same number of miles of water edge and open water habitat. There is some potential of increasing the concentration of natural salts in the remaining drainage water returned to the Sacramento River due to the connate ground water source.

Analysis of This Measure:

The results of the analysis shows that 37,100 acre-feet, or 97 percent of the estimated seepage losses from the canal system is lost to the drainage system and Sacramento River from 34.4 miles, or 21 percent, of the ditch system. Also, 19,700 acre-feet, or 52 percent, of the water is lost from 3 percent of the ditch system. If a project was selected to line the latter areas, or approximately 5.0 miles, the cost of installation would be $2,283,000 and the cost of the saved water would be slightly more than $17 per acre-foot. The cost of lining the 34.4 miles would be $12,800,000 for a cost of about $51 per acre-foot.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Conversion to Pipeline

The Present Conditions are the same as the conversion to lined ditch option.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible for only some of the ditches in the service area. Only the ditch segments where the soil allows for large amounts of water seepage were considered for piping.

Maintenance of the piped system would require replacement every 25 years.

D. Estimated pipeline maintenance costs are $1,500 per pipe mile. The estimated cost of 34 miles of a pipeline system is $75 million. The minimum average annual cost would be $9.5 million. The estimated cost per acre-foot would be $225 and could be much higher.

The Company would need to cover the installation and maintenance costs of the pipe work through landowner fees. Currently the annual per acre fee is $14.50. This added cost would raise the annual fee for the assessed gross acres of 50,083 by about $190 per acre.

The Company could reduce pumping costs because less water would need to be diverted from the Sacramento River. If you assume a pumping cost of $1.75 per acre foot, the savings is $73,500 or $1.47 per gross acre in the area (50,083 acres).

E. The Company may be able to manage the water delivery more easily and more efficiently. The landowners would most likely be able to order more precisely the amount of water needed and not be required to modify their current farming operations.

F. The drain water reuse that currently takes place in the basin may no longer be possible. The drain water reuse would need to be replaced by additional water purchases by the growers. Approximately 42,000 acre-feet of water would be saved with this measure.

G. Piping the ditches would eliminate 613 acres of open water habitat and 840 acres of water edge habitat.

There is the potential of increasing the concentration of natural salts in the basin due to the connate ground water source. The drain water that remains to be returned to the Sacramento River may involve higher concentrations of salts.

Analysis of This Measure:

Converting from ditch systems to pipeline systems has been offered as an economical water conservation option offering advantages for on-demand water delivery and reduced seepage and evaporation losses. Pipeline installation would not be less expensive than channel lining but the assumption is made that it could be done for 1.5 times the cost.

One advantage of a pipeline system is the on-demand feature it could provide. However, the Company would still need to order water three days in advance for expected customer needs. The customer could then "turn off" the water at the turnout. This would result in spillage back to the river at the pumping plant and no net savings. If spillage at the river is desired, the canal system could be modified by the addition of automatic gates which could respond to changes in downstream demand. Presently the potential amount of spillage remains unquantified.

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Water seeping from the ditches in this area is not actually "lost". The ground water is so shallow that this water generally seeps into the drain ditches and is discharged into the Sacramento River.

It should be pointed out that the water lost to the drainage ditch system and Sacramento River would need to be replaced for the downstream users. If the Company reduced its order from Shasta Dam because it became more internally efficient, the downstream water users would not have the "excess" water the district had been releasing to the system. The portion of the Company water users which supplement their water purchases by pumping from the drainage system would also need to purchase water to make up for the reduced water in the drainage system.

14. Construction or Lining of Regulatory Reservoirs Construct or line regulating reservoirs.

Present Conditions:

Currently, the Company's control of water delivery is limited. With the installation of an in-basin water storage facility, deliveries could be more efficiently provided. Additional channel controls would also help in the regulation of water deliveries.

There is no Company regulating reservoir; however, the main canals have significant storage capacity and function as regulating reservoirs.

Factors Considered:

A. This measure is applicable to the area.

B. This measure is technically feasible. The Company would need to gain the support of the landowners and provide appropriate incentives to implement a significant modification to the way growers manage their farming operations.

D. Growers would be required to pay for the infrastructure and operation costs in terms of higher assessments. With an estimated 50,083 acres in the area, the per acre cost would go up from the current $14.50 per acre. The Company could reduce pumping costs because less water would need to be diverted from the Sacramento River. If you assume a pumping cost of $1.75 per acre foot, the savings is $2.62 per gross acre.

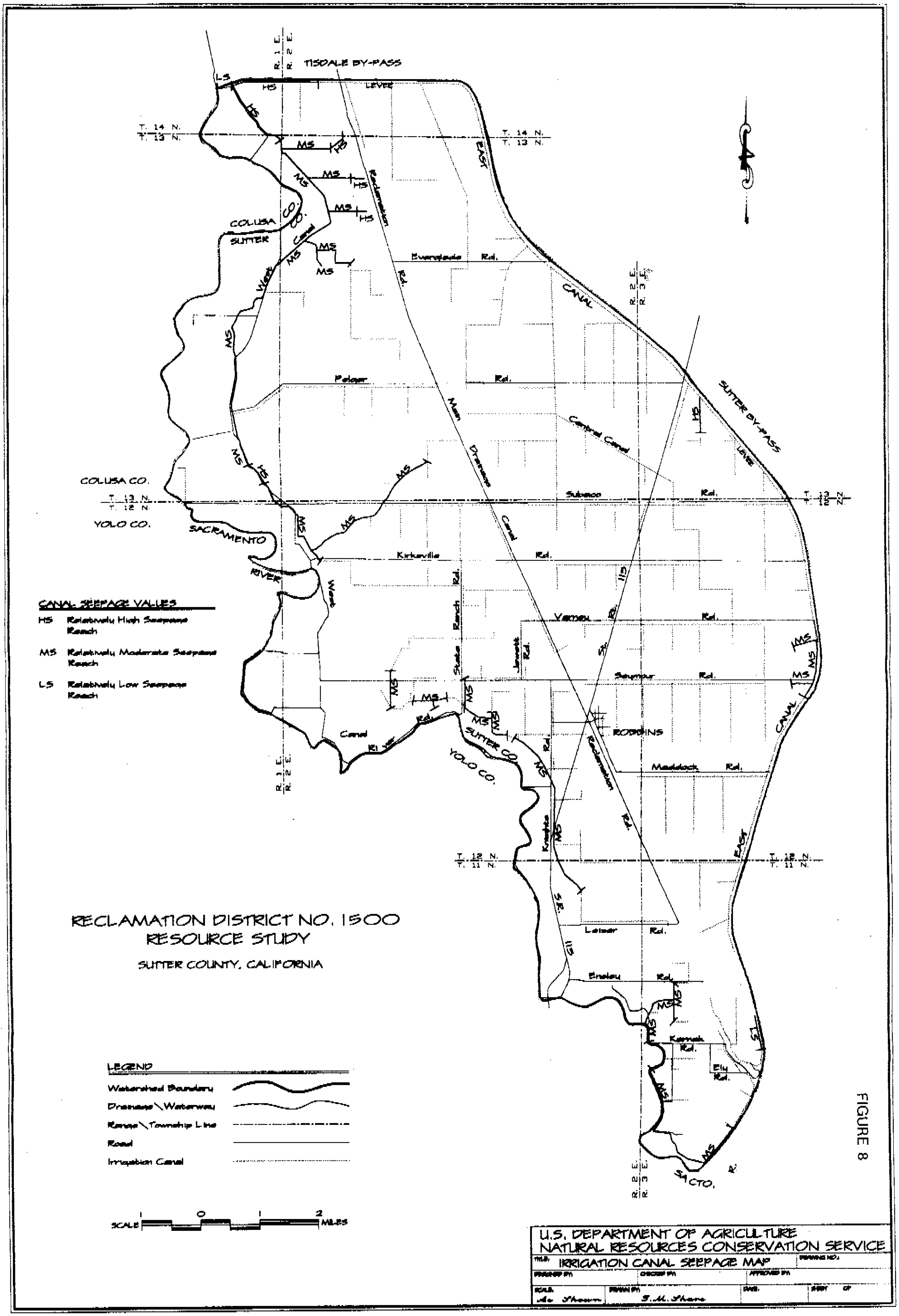
The Company would be faced with the purchase cost of land, cost associated with construction of the water-holding basin and associated infrastructure, and annual operation and maintenance expense.

Some agricultural land would need to be taken out of production for the water holding basin.

E. This measure would increase the flexibility of water delivery.

F. Between 3,600 to 76,000 acre-feet of water could be saved based on the types of improvements made. This range is dependent on the BOR allotment received, the salinity of the stored water, and the ability of the District to find the facilities to build a reservoir.

G. Some additional wetland habitat could be created with the development of a water-holding basin.



RECLAMATION DISTRICT NO. 1500
RESOURCE STUDY
SUTTER COUNTY, CALIFORNIA
CANAL SEEPAGE VALUES
HS Relatively High Seepage Reach
MS Relatively Moderate Seepage Reach
LS Relatively Low Seepage Reach
LEGEND
Watershed Boundary
Drainage\Waterway
Range\Township Line
Road
Irrigation Canal
SCALE 1 0 1 2 MILES
TISDALE BY-PASS
LEVEE
EAST CANAL
SUTTER BY-PASS
COLUSA CO.
SUTTER CO.
YOLO CO.
SACRAMENTO RIVER
SACTO. R.
Everglade Rd.
Pelger Rd.
Central Canal
Main Drainage Canal
Reclamation Rd.
Subaco Rd.
Kirkville Rd.
Varney Rd.
Seymour Rd.
Maddock Rd.
State Ranch Rd.
Jewett Rd.
ROBBINS
Leiser Rd.
Ensley Rd.
Kornah Rd.
Ely Rd.
Knights
S.R. 113
T. 14 N.
T. 13 N.
T. 12 N.
T. 11 N.
R. 1 E.
R. 2 E.
R. 3 E.

FIGURE 8

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
TITLE: IRRIGATION CANAL SEEPAGE MAP
SCALE: As Shown
DRAWN BY: J. M. Shore

(A) applicability to the district, (B) technical feasibility, (D) financial feasibility for the district, (E) improved efficiency of water delivery and use, (F) quantity of water to be saved, and (G) environmental impacts.

Analysis of This Measure:

Installation of a regulating reservoir without changing the canal control systems and installation of a water return system would not serve any function without the implementation of a combination of measures. The main canals currently serve as storage.

Section Summary

Table 7 summarizes the issues addressed in this section.

TABLE 7: SUMMARY OF ISSUES

Potential Water Conservation Treatments	Factors Considered When Additional Water Conservation Measures Were Analyzed							
	(a) Applicable to District?	(b) Technically Feasible	(c) Legal Under State/Fed. Law	(d) Cost Considerations		(e) Improved Efficiency Water Use/ Delivery	(f) Amount of Water Saved (acre feet) [2]	(g) Environmental Impacts (+,-)
				Company	Land Owner			
1. Incentive Pricing	Yes	Yes	[1]	Example Range: Increased Cost = [3] $90,000/yr to Reduced Cost = $210,000/yr. (Depends on program management costs and water use in response to pricing change.)	Example Range: Reduced Cost = [3] $90,000/yr to Increased Cost = $210,000/yr. (Depends on program management costs and water use in response to pricing change.)	Yes	3,600 - 10,200	Wetland loss.
2. On-farm Program	Yes	Yes	[1]	Unknown	$5 to $61 acre/yr.	Yes	240 - 3,600	Wetland loss. Salt Build-up.
3. Drought Plan (Already Implemented)	Yes	Yes	[1]	Unknown	Unknown	Yes	Currently achieving under present management.	Salt Build-up Less Volume in River.
4. Water Transfers	Yes	Yes	[1]	Unknown	Unknown	No	- 0 -	Wetland increase.
5. Conjunctive Use	No	No	[1]	N/A	N/A	N/A	N/A	N/A
6. Land Management	Yes	Yes	[1]	Limited	Some landowners may lose some income associated with farm land that is no longer irrigated.	No	Yes	Habitat loss. Salt Build-up.
7. District Operational Practice Changes	Yes	Uncertain	[1]	Management and equipment costs.	N/A	Yes	- 0 - Unless combined with regulating reservoir.	Habitat loss. Salt Build-up.
8. Irrigation System Scheduling	Yes	Yes	[1]	+	N/A	Yes	3,600	Habitat loss. Salt Build-up.
9. On-farm Irrigation Scheduling	Yes	Yes	[1]	+/-	Additional Management Costs	Yes	3,600	Habitat loss. Salt Build-up.
10. Pump Efficiency Evaluations	Yes	Yes	[1]	Some energy cost savings.	N/A	Yes	- 0 -	Negligible.
11. Distribution Control	Yes	No	[1]	+ Equipment and personnel cost.	N/A	Yes	10,200 When combined with regulating reservoir.	Negligible.
12. Reuse Systems	Yes	Yes	[1]	$360,000 +/yr and pumping costs	$30/ acre/yr	Yes	Up to 52,000 (Currently up to 32,000 ac-ft are being reused.)	Significant salt build-up. Reduced volume to Sacramento River. Habitat Loss
13. System Lining	Yes	Yes	[1]	A: 34 miles - $1.8 million/yr B: 5 miles - $337,000/yr C: 162 miles of pipeline - $9.5 million/yr	A: $37 /acre/yr B: $7 /acre/yr C: $190 /acre/yr (Cost passed on from company.)	Yes	20,000 to 40,000	Habitat loss. Increase salinity.
14. Regulatory Reservoir	Yes	Yes	[1]	+ $250,000 to $1 million	Company costs would be passed on to landowner.	Yes	3,600 to 52,000 (0 unless included with other systems modifications.)	Increased habitat. Salt Build-up

1 - Legal issues were not explored in this study.

2 - "Saved" water values indicate the net change in the amount of Sacramento River water circulated through the Reclamation District Irrigation System.

3 - Example water cost range assuming a tier price of $30/acre-ft. for excess irrigation water application.

SECTION V

OPPORTUNITIES AND CONSIDERATIONS

The three objectives for this study identified at the beginning of this document were:

1. Present a resource inventory and assessment of the present use of all the area's water, soil, and environmental resources.

2. Discuss the enhancement opportunities of these resources.

3. Predict the potential impacts of significant changes in resource uses or allocations.

Addressing these objectives in the same order:

1. Present a resource inventory and assessment of the present use of all the area's water, soil, and environmental resources.

A resource inventory is presented in Sections II and III. Instead of presenting a separate assessment of these resources, the information developed in the inventory was used to assess the Bureau of Reclamation water conservation measures recommended for consideration in the publication "Draft Guidelines and Criteria for Water Conservation Plans". The results of these assessments demonstrate that, while there is some room for slight improvements, the local growers, Sutter Mutual Water Company, and Reclamation District 1500 are efficiently utilizing the water resources available to them.

One example of this is the relatively small amount of water that could be saved by the implementation of the suggested water conservation measures. Up to 3,600 acre-feet, or two percent of the District's total water diverted in 1993, could be saved with the implementation of tiered pricing, on-farm program incentives, or changes in irrigation or delivery scheduling. Many of the measures, in assuming the acre-feet of water that can be saved, are very dependent on the BOR allotment received and the quality of the water found in the drains. It is impossible to predict if these water amounts can be relied on under actual circumstances.

It is also a fact that due to the high concentrations of salts in the subsurface water in this area, salinity levels in both the surface water and soil may increase to very high levels. The fact that many crops are grown productively implies that the growers are handling their irrigation and drainage well and salinity levels are being kept within the limits needed for agricultural uses. The high salinity of the connate water affects the drain water, leaching requirement, and habitat values, making for very restrictive solutions.

2. Discuss the enhancement opportunities of these resources.

As mentioned before, while the local growers are doing a good job of managing their resources, there are some opportunities for enhancement.

Fish and Wildlife Enhancement Opportunities

Wildlife, in general, needs four essential things to be a part of any environment. Two of these are obvious: food and water. The other two things are less obvious and more difficult to assess: suitable

Wildlife, in general, needs four essential things to be a part of any environment. Two of these are obvious: food and water. The other two things are less obvious and more difficult to assess: suitable cover and successful reproduction needs. Together these four elements will determine the suitability of a particular habitat to attract and maintain a particular animal and the quality of these elements will determine the number of individuals that a habitat will support, or the carrying capacity. While this is not the complete picture, it is useful to keep these four elements in mind because, if one of them is limited or missing, the wildlife populations will definitely be affected. Migratory animals, for example, may not need each element to be in a specific habitat all the time, but animals that spend their lives in one area will need each element sometime during their life cycle.

Present agricultural practices and the water distribution system in the study area are beneficial to many fish and wildlife species. Cropping patterns, ditch maintenance, and water management provide abundant food and water for wildlife. Less frequent clearing of ditches, increasing use of no-till agriculture, and tree plantings are improving the amount of permanent cover available for wildlife. Opportunities to improve overall habitat diversity and wildlife population levels still exist.

Some general opportunities exist to enhance present management to favor improved fish and wildlife populations. Both the availability of waterfowl feeding areas and reproduction success can be enhanced by continuing the present trend towards early flooding of rice fields and harvesting grains after waterfowl nesting is completed, usually in June. Combining this with more permanent tailwater holding ponds where young ducks can escape predation and grain harvest activities will improve their survival after they leave the nest.

The SMWC's Water Management Plan identifies the possible installation of fish screens on pipes which remove water from the Sacramento River as an opportunity. It is predicted that future pumping from the river will be controlled at certain times of the year and/or fish exclusion devices at the pump inlet will be required. The Company has become well informed on this issue and is ascertaining the best design and related costs of controlling fish at the pump inlet (SMWC, 1992).

The following are specific recommendations for wildlife management in southern Sutter County.

Waterfowl

One of the best ways to attract migratory waterfowl is to provide food and water. This means the landowners should not drain ponds and marshes or let them dry out during the season they want to attract waterfowl. Food can be provided by flooding harvested crops such as rice, corn, millet, wheat, and barley in the fall just prior to the arrival of the first flights. This practice may be limited by flood control and drainage requirements and responsibilities during the winter. Low-lying areas can be planted and allowed to flood naturally when it rains, or some extra rows can be planted near wetlands and left for wildlife use.

Ducks, like mallards and wood ducks, do stay in the area year round because cover is provided and they can reproduce. Mallards nest in dry areas covered with grasses about 18 inches high that are relatively free from disturbance by equipment or predators. Wheat fields planted in the fall benefit mallards. The harvest of grain in June allows the broods to move out of the fields. The mallards move their broods to ponds, ditches, and streams to feed on water plants, insects, and other invertebrates, so these brooding areas should be nearby for optimum success.

Wood ducks nest in tree cavities. Establishing nesting boxes near rice fields or wet areas will favor them, especially if nesting boxes are provided on young trees until natural cavities form. Similar to mallards, nearby brooding water is important. Establishing windbreaks or shelterbelts anywhere near the rice fields or bypass areas will attract and maintain wood ducks in addition to the general environmental benefits.

Upland Game

The term upland game includes wildlife like quail, pheasants, and cottontail rabbits. They are present year round so food and cover are especially important. Water would only rarely be a limiting factor in this area. Cover is probably the most limiting factor at present. Cover provides protection from extremes of heat and cold, allows successful reproduction, and provides protection from predators. Fence rows, ditch banks, equipment storage areas, power line or other rights-of-way, odd corners, or wet spots can be developed or maintained to provide good cover. Windbreaks and shelterbelts can be designed to provide both food and cover. The elimination of burning or mowing, or the delay until after nesting is complete, will improve habitat for upland game. Leaving patchy crop areas unharvested will provide both food and cover. So will planting fence rows, ditch banks, and row or field edges to native grasses with clovers. When properly done, this kind of planting will usually out-compete weeds and reduce the need to burn or spray. Orchard prunings can be piled and left to provide cover. Marginal lands can often be managed for wildlife, and the hunting rights sold for more than the crops would be worth.

Regional Levee and Berm Management

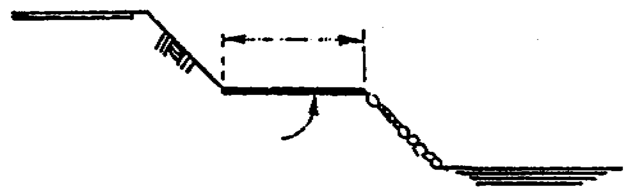
It would provide additional wildlife habitat to change the present maintenance of the 60 miles of flood protection levees surrounding the study area. Current practices include the complete removal of all vegetation on the levees by burning and/or discing. Considerable improvement in both fish and wildlife numbers have been achieved elsewhere in the state by planting the levee with perennial grass cover to compete with weed species, and by the re-establishment of the riparian vegetation on the bench areas along the inside of the levees. Both of these measures will reduce the recurring by weed species and will enhance use by fish or wildlife, as well as the recreational values, by providing shade and protection from the wind. The establishment of some demonstration plantings could test this approach for use on this area. Tree nesting birds like the wood duck or Swainson's hawk will be favored by improving the number of cottonwoods near the wetlands. Upland game like pheasants will also nest and use the areas for escape cover during nearby agricultural operations.

As mentioned previously, there are several demonstration areas in northern California where vegetation has been established as part of the maintenance program. Some aspects of these projects would benefit wildlife populations in the study area and should be tested. Several of the native perennial grasses are non-invasive but once the grasses become established will compete against weeds like yellow nutsedge. This makes them useful to protect from surface erosion, without spreading into nearby cropland. Creeping wild rye, blue wildrye, and purple needlegrass are examples of species which can be used to accomplish some of the recommendations for wildlife management without creating a weed problem. Some benches or berms inside the levee can also be planted with this grass and tree cover without compromising levee integrity. An example of the engineer's drawings for a project in the Sacramento River is enclosed (see Figure 9).

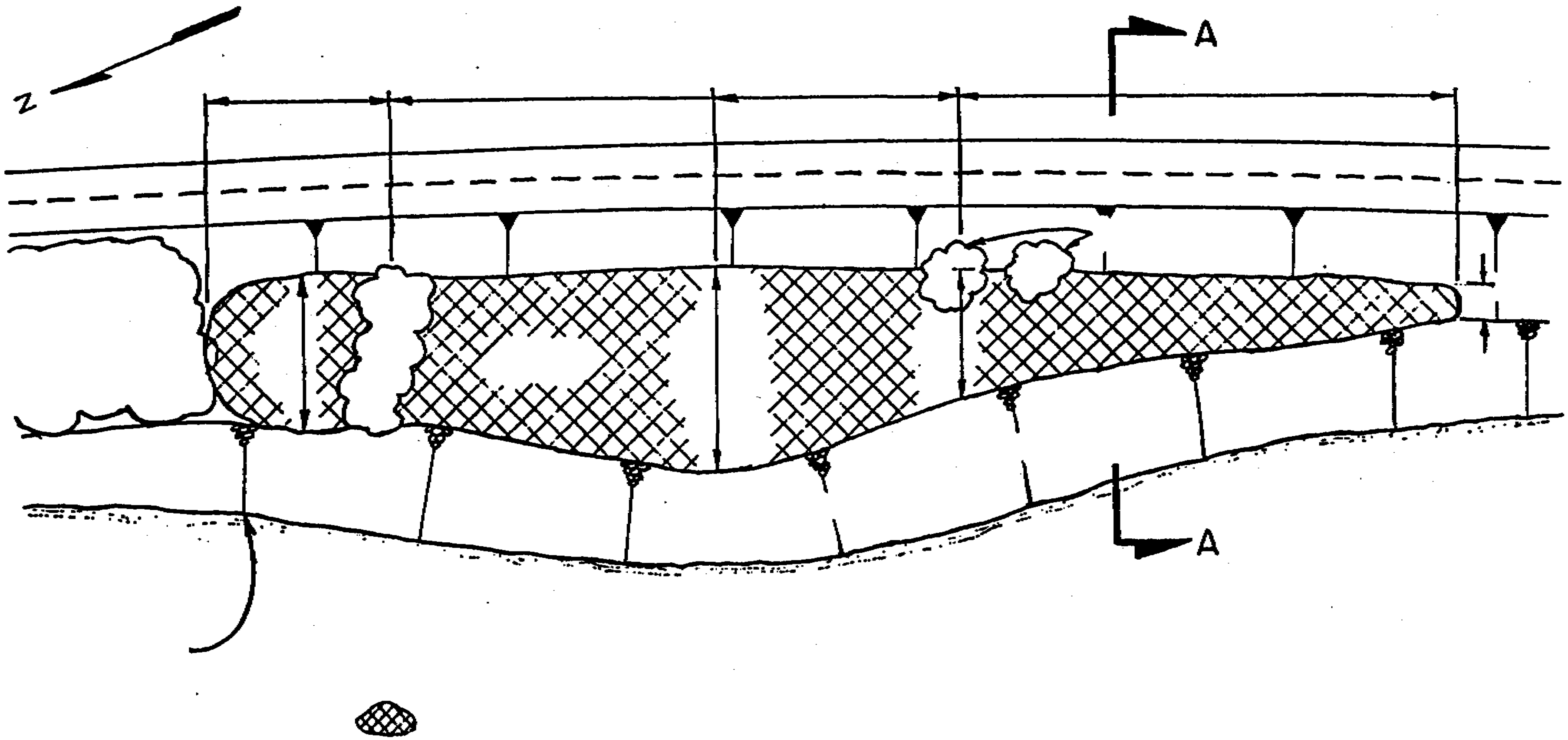
Levee integrity needs to be of paramount concern. With an increase of riparian vegetation a more proactive management program is necessary to prevent levee failure from falling trees. Procedures to assess risk from falling trees have been developed for street trees. A similar program would be needed in order to improve riparian cover and maintain levee and berm protection.

Landowner Assistance

All of the above recommendations can be used in various combinations depending on site-specific conditions. Technical, and sometimes cost share, assistance is available from agencies like the USDA Natural Resources Conservation Service, University of California Cooperative Extension Service, California Department of Fish and Game, and the California Department of Forestry and Fire Protection.



SECTION A-A



SACRAMENTO RIVER RM 19.2 LEFT

NOT TO SCALE

FIGURE 9

Opportunities For Water Conservation

There are some limited opportunities for water conservation on 12,000 acres in the study area to be improved. The amount of total water saved would not exceed 3,600 acre-feet for these acres. Some preliminary suggestions coming from AGWATER runs include eliminating one or two unnecessary early irrigations, switching to sprinklers for early irrigations, and shortening sets. Some of the BOR measures which would accomplish this include on-farm incentive programs, incentive pricing, and on-farm irrigation scheduling.

Lining or piping the distribution ditches could save from 19,700 to 42,000 acre-feet of water per year. This measure would prevent the seepage from these ditches along the segments where the soil type allows excessive amounts of seepage. The cost of these options is significant, however. Additionally, the cost to wildlife habitat is significant.

It appears that the most cost effective water conservation method for Reclamation District 1500 to implement is grower and community education for on-farm water management.

Opportunities For Education/Information Programs

A public education and information campaign needs to be a part of any area-based program. There are many ways to educate and inform the public.

Information on water conservation can be handed out or mailed along with local water bills. Goal-oriented information should be provided so everyone knows what the needs are for a successful program.

Since landowners most often seek information and advice from neighboring landowners, recruiting growers who have implemented conservation practices or have effectively conserved water to assist in tours and field demonstrations could help provide landowners with good information.

3. Predict the potential impacts of significant changes in resource uses or allocations.

The third objective was to predict the potential impacts of significant changes in resource uses or allocations. It was determined through interviews that growers are not planning any significant changes in resources uses or allocations in the foreseeable future unless irrigation water costs change significantly. The growers were able to cope during the recent water cutbacks and had no need to change cropping patterns. There are no plans to dramatically change land use in the study area. There is a stable and healthy farming economy with a stable crop pattern. Processing tomatoes and rice will most likely continue to be the crop mainstays in the area.

If water prices ever increased to make the cost of growing rice prohibitive, a 50 percent reduction in rice acreage might result and would possibly create an overall reduction in water orders. Assume that the rice acreage is converted to a similar crop mix of locally grown crops with a similar water use pattern. Cropland may increase by 9,000 acres to a total of 51,000 acres. The water diverted for rice would decrease from 107,250 acre-feet to 53,625 acre-feet. If the 9,000 acres were irrigated at an 80 percent efficiency, the irrigation water order for these crops would be 20,625 acre-feet. This is a net reduction in ordered water of 33,000 acre-feet. The water which would reach Karnak from the 9,000 acres of cropland would be 4,125 acre-feet.

The bean, melon, and tomato crops use an estimated 10,300 acre-feet of water from the ground water table. If it is assumed that the ground water table would remain the same, the net effect would be a decrease in the discharge at Karnak or an increase in connate and lateral flow. There would also be an unquantified decrease in the better quality subsurface water available to the surrounding cropland. This would either require an unknown increase in irrigation water for leaching salts or a potential increase in the risk of soil salinization. The impacted landowners include all of the melon growers, and a significant number of bean and tomato growers.

If the water needs of the crops can be met from the ground water table and there is no salt increase in connate and lateral flows, then the net effect would be an increase in the salt concentration of the discharge water of Karnak. If the rim flows increase, there would be no net increase because the lateral flows come from the river system. However, if connate flows increase, then the salt concentration could increase significantly.

Recommendation For Future Study

Before considering ground water as a water supply in the study area, three-dimensional isoconcentration maps need to be developed for the underlying ground water and transmissivities within the ground water body, with all connecting water bodies determined. The U.S. Geological Survey (USGS) should be consulted to develop an investigation plan.

Once this basic data set is available, a well management plan and accompanying model can be developed to prevent contamination of the existing freshwater mass, and well interference and mining of the Sacramento River. The USGS should be consulted to develop a well management plan and develop a ground water model for the project area.

An attempt was made in this report to account for salt transfers in the basin. This attempt failed to give an accounting of inflows versus outflows because it was only possible to deal with one point in time as opposed to a dynamic state. A previous attempt by Tanji (Tanji, 1975) was also inadequate. In addition to the preceding recommendations to enhance the understanding of water transfers, salt fluxes across water boundaries need to be quantified. These studies need to encompass the spatial and temporal variances peculiar to this basin.

An increase in salinity would impact the habitat system in the area and a reduction of rice acreage would reduce the open water areas for ducks.

Drastic cutbacks in water availability would most likely lead to an increase in soil salinity and have an adverse impact on wildlife habitats and populations. Water allocations below the current levels would change cropping patterns and create a loss of economic stability in the region.

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With special thanks to the assistance provided by the board members and employees of the Sutter Mutual Water Company and Reclamation District 1500 and Max Sakato, General Manager.

APPENDIX A

WILDLIFE HABITAT RELATIONSHIP DATABASE PRINTOUT

08:34:24 CALIFORNIA WILDLIFE HABITAT RELATIONSHIPS SYSTEM 09/20/94

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SPECIES SUMMARY LIST

SELECTION CRITERIA:

Locations:
SUTTER COUNTY

Habitats:

1	VALLEY OAK WOODLAND	SEEDLING TREE			(1)
2	VALLEY OAK WOODLAND	SAPLING TREE	SPARSE	10-24%	(2S)
3	VALLEY OAK WOODLAND	SAPLING TREE	OPEN	25-39%	(2P)
4	VALLEY OAK WOODLAND	SAPLING TREE	MODRTE	40-59%	(2M)
5	VALLEY OAK WOODLAND	SAPLING TREE	DENSE	60-100%	(2D)
6	VALLEY OAK WOODLAND	POLE TREE	SPARSE	10-24%	(3S)
7	VALLEY OAK WOODLAND	POLE TREE	OPEN	25-39%	(3P)
8	VALLEY OAK WOODLAND	POLE TREE	MODRTE	40-59%	(3M)
9	VALLEY OAK WOODLAND	POLE TREE	DENSE	60-100%	(3D)
10	VALLEY OAK WOODLAND	SMALL TREE	SPARSE	10-24%	(4S)
11	VALLEY OAK WOODLAND	SMALL TREE	OPEN	25-39%	(4P)
12	VALLEY OAK WOODLAND	SMALL TREE	MODRTE	40-59%	(4M)
13	VALLEY OAK WOODLAND	SMALL TREE	DENSE	60-100%	(4D)
14	VALLEY OAK WOODLAND	MED/LARGE TREE	SPARSE	10-24%	(5S)
15	VALLEY OAK WOODLAND	MED/LARGE TREE	OPEN	25-39%	(5P)
16	VALLEY OAK WOODLAND	MED/LARGE TREE	MODRTE	40-59%	(5M)
17	VALLEY OAK WOODLAND	MED/LARGE TREE	DENSE	60-100%	(5D)
18	VALLEY-FOOTHILL RIPARIAN	SEEDLING TREE			(1)
19	VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	SPARSE	10-24%	(2S)
20	VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	OPEN	25-39%	(2P)
21	VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	MODRTE	40-59%	(2M)
22	VALLEY-FOOTHILL RIPARIAN	SAPLING TREE	DENSE	60-100%	(2D)
23	VALLEY-FOOTHILL RIPARIAN	POLE TREE	SPARSE	10-24%	(3S)
24	VALLEY-FOOTHILL RIPARIAN	POLE TREE	OPEN	25-39%	(3P)
25	VALLEY-FOOTHILL RIPARIAN	POLE TREE	MODRTE	40-59%	(3M)
26	VALLEY-FOOTHILL RIPARIAN	POLE TREE	DENSE	60-100%	(3D)
27	VALLEY-FOOTHILL RIPARIAN	SMALL TREE	SPARSE	10-24%	(4S)
28	VALLEY-FOOTHILL RIPARIAN	SMALL TREE	OPEN	25-39%	(4P)
29	VALLEY-FOOTHILL RIPARIAN	SMALL TREE	MODRTE	40-59%	(4M)
30	VALLEY-FOOTHILL RIPARIAN	SMALL TREE	DENSE	60-100%	(4D)
31	VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	SPARSE	10-24%	(5S)
32	VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	OPEN	25-39%	(5P)
33	VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	MODRTE	40-59%	(5M)
34	VALLEY-FOOTHILL RIPARIAN	MED/LARGE TREE	DENSE	60-100%	(5D)
35	ANNUAL GRASS	SHORT HERB	SPARSE	2-09%	(1S)
36	ANNUAL GRASS	SHORT HERB	OPEN	10-39%	(1P)

SPECIES SUMMARY LIST

Habitats: (Cont)

37 ANNUAL GRASS	SHORT HERB	MODRTE	40-59%	(1M)
38 ANNUAL GRASS	SHORT HERB	DENSE	60-100%	(1D)
39 ANNUAL GRASS	TALL HERB	SPARSE	2-09%	(2S)
40 ANNUAL GRASS	TALL HERB	OPEN	10-39%	(2P)
41 ANNUAL GRASS	TALL HERB	MODRTE	40-59%	(2M)
42 ANNUAL GRASS	TALL HERB	DENSE	60-100%	(2D)
43 PERENNIAL GRASS	SHORT HERB	SPARSE	2-09%	(1S)
44 PERENNIAL GRASS	SHORT HERB	OPEN	10-39%	(1P)
45 PERENNIAL GRASS	SHORT HERB	MODRTE	40-59%	(1M)
46 PERENNIAL GRASS	SHORT HERB	DENSE	60-100%	(1D)
47 PERENNIAL GRASS	TALL HERB	SPARSE	2-09%	(2S)
48 PERENNIAL GRASS	TALL HERB	OPEN	10-39%	(2P)
49 PERENNIAL GRASS	TALL HERB	MODRTE	40-59%	(2M)
50 PERENNIAL GRASS	TALL HERB	DENSE	60-100%	(2D)
51 FRESH EMERGENT WETLAND	SHORT HERB	SPARSE	2-09%	(1S)
52 FRESH EMERGENT WETLAND	SHORT HERB	OPEN	10-39%	(1P)
53 FRESH EMERGENT WETLAND	SHORT HERB	MODRTE	40-59%	(1M)
54 FRESH EMERGENT WETLAND	SHORT HERB	DENSE	60-100%	(1D)
55 FRESH EMERGENT WETLAND	TALL HERB	SPARSE	2-09%	(2S)
56 FRESH EMERGENT WETLAND	TALL HERB	OPEN	10-39%	(2P)
57 FRESH EMERGENT WETLAND	TALL HERB	MODRTE	40-59%	(2M)
58 FRESH EMERGENT WETLAND	TALL HERB	DENSE	60-100%	(2D)
59 PASTURE				(1)
60 BARREN				(1)
61 DECIDUOUS ORCHARD	SEED/SAPLING TREE			(1)
62 DECIDUOUS ORCHARD	YOUNG TREE			(2)
63 DECIDUOUS ORCHARD	MATURE TREE			(3)
64 IRRIGATED GRAIN CROPS	SEEDLING TREE			(1)
65 DRYLAND GRAIN CROPS	SEEDLING TREE			(1)
66 IRRIGATED ROW AND FIELD CROPS	SEEDLING TREE			(1)
67 RIVERINE	OPEN WATER			(1)
68 RIVERINE	SUBMERGED	ORGANIC		(20)
69 RIVERINE	SUBMERGED	MUD		(2M)
70 RIVERINE	SUBMERGED	SAND		(2S)
71 RIVERINE	SUBMERGED	GRAVEL/COBBLE		(2G)
72 RIVERINE	SUBMERGED	RUBBLE/BOULDERS		(2R)
73 RIVERINE	SUBMERGED	BEDROCK		(2B)
74 RIVERINE	PERIODIC FLOODING	ORGANIC		(30)
75 RIVERINE	PERIODIC FLOODING	MUD		(3M)
76 RIVERINE	PERIODIC FLOODING	SAND		(3S)
77 RIVERINE	PERIODIC FLOODING	GRAVEL/COBBLE		(3G)

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SPECIES SUMMARY LIST

Habitats: (Cont)

78 RIVERINE	PERIODIC FLOODING	RUBBLE/BOULDERS	(3R)
79 RIVERINE	PERIODIC FLOODING	BEDROCK	(3B)
80 RIVERINE	SHORE	ORGANIC	(4O)
81 RIVERINE	SHORE	MUD	(4M)
82 RIVERINE	SHORE	SAND	(4S)
83 RIVERINE	SHORE	GRAVEL/COBBLE	(4G)
84 RIVERINE	SHORE	RUBBLE/BOULDERS	(4R)

Elements Excluded:
JETTY
KELP
PACK STATIONS
SALT PONDS
SPRINGS, HOT
SPRINGS, MINERAL
STEEP SLOPE
TIDEPOOLS
WHARF

ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	CPS
A014	CALIFORNIA SLENDER SALAMANDER	Batrachoseps attenuatus	PLETHODONTIDAE		
A028	WESTERN SPADEFOOT	Scaphiopus hammondi	PELOBATIDAE		
A032	WESTERN TOAD	Bufo boreas	BUFONIDAE		
A039	PACIFIC TREEFROG	Hlya regilla	HYLIDAE		
A040	RED-LEGGED FROG	Rana aurora	RANIDAE		
A043	FOOTHILL YELLOW-LEGGED FROG	Rana boylei	RANIDAE		
A046	BULLFROG	Rana catesbeiana	RANIDAE	9	
B006	PIED-BILLED GREBE	Podilymbus podiceps	PODICIPEDIDAE		
B010	WESTERN GREBE / CLARK'S GREBE	Aechmophorus occidentalis / Clarkii	PODICIPEDIDAE		
B049	AMERICAN BITTERN	Botaurus lentiginosus	ARDEIDAE		
B050	LEAST BITTERN	Ixobrychus exilis	ARDEIDAE	6	
B053	SNOWY EGRET	Egretta thula	ARDEIDAE		
B057	CATTLE EGRET	Bubulcus ibis	ARDEIDAE		
B058	GREEN-BACKED HERON	Butorides striatus	ARDEIDAE		
B062	WHITE-FACED IBIS	Plegadis chihi	THRESKIORNITHIDAE	6	
B067	TUNDRA SWAN	Cygnus columbianus	ANATIDAE		
B070	GREATER WHITE-FRONTED GOOSE	Anser albifrons	ANATIDAE	9	
B071	SNOW GOOSE	Chen caerulescens	ANATIDAE	9	
B072	ROSS' GOOSE	Chen rossii	ANATIDAE	9	
B075	CANADA GOOSE	Branta canadensis	ANATIDAE	9	

SPECIES SUMMARY LIST

ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 1 F E	2 F T	3 C E	4 C T	5 C P	6 C S	7 F S	8 B S	9 H	C P S
B076	WOOD DUCK	Aix sponsa	ANATIDAE									9	
B077	GREEN-WINGED TEAL	Anas crecca	ANATIDAE									9	
B079	MALLARD	Anas platyrhynchos	ANATIDAE									9	
B080	NORTHERN PINTAIL	Anas acuta	ANATIDAE									9	
B082	BLUE-WINGED TEAL	Anas discors	ANATIDAE									9	
B083	CINNAMON TEAL	Anas cyanoptera	ANATIDAE									9	
B085	GADWALL	Anas strepera	ANATIDAE									9	
B086	EURASIAN WIGEON	Anas penelope	ANATIDAE									9	
B089	CANVASBACK	Aythya valisineria	ANATIDAE										
B090	REDHEAD	Aythya americana	ANATIDAE									9	
B091	RING-NECKED DUCK	Aythya collaris	ANATIDAE									9	
B094	LESSER SCAUP	Aythya affinis	ANATIDAE									9	
B105	COMMON MERGANSER	Mergus merganser	ANATIDAE									9	
B108	TURKEY VULTURE	Cathartes aura	CATHARTIDAE										
B111	BLACK-SHOULDERED KITE	Elanus caeruleus	ACCIPITRIDAE					5					
B113	BALD EAGLE	Haliaeetus leucocephalus	ACCIPITRIDAE	1		3		5					
B114	NORTHERN HARRIER	Circus cyaneus	ACCIPITRIDAE						6				
B115	SHARP-SHINNED HAWK	Accipiter striatus	ACCIPITRIDAE						6				
B116	COOPER'S HAWK	Accipiter cooperii	ACCIPITRIDAE						6				
B119	RED-SHOULDERED HAWK	Buteo lineatus	ACCIPITRIDAE										
B121	SWAINSON'S HAWK	Buteo swainsoni	ACCIPITRIDAE				4						
B123	RED-TAILED HAWK	Buteo jamaicensis	ACCIPITRIDAE										
B127	AMERICAN KESTREL	Falco sparverius	FALCONIDAE										
B131	PRAIRIE FALCON	Falco mexicanus	FALCONIDAE							7			
B133	RING-NECKED PHEASANT	Phasianus colchicus	PHASIANIDAE									9	
B140	CALIFORNIA QUAIL	Callipepla californica	PHASIANIDAE									9	
B145	VIRGINIA RAIL	Rallus limicola	RALLIDAE										
B146	SORA	Porzana carolina	RALLIDAE										
B148	COMMON MOORHEN	Gallinula chloropus	RALLIDAE									9	
B150	SANDHILL CRANE	Grus canadensis	GRUIDAE					5					
B159	MOUNTAIN PLOVER	Charadrius montanus	CHARADRIIDAE										
B199	COMMON SNIPE	Gallinago gallinago	SCOLOPACIDAE										
B250	ROCK DOVE	Columba livia	COLUMBIDAE									9	
B259	YELLOW-BILLED CUCKOO	Coccyzus americanus	CUCULIDAE			3							
B260	GREATER ROADRUNNER	Geococcyx californianus	CUCULIDAE										
B262	COMMON BARN OWL	Tyto alba	TYTONIDAE										
B264	WESTERN SCREECH OWL	Otus kennicottii	STRIGIDAE										
B265	GREAT HORNED OWL	Bubo virginianus	STRIGIDAE										
B267	NORTHERN PYGMY OWL	Glaucidium gnoma	STRIGIDAE										
B269	BURROWING OWL	Athene cunicularia	STRIGIDAE						6				
B272	LONG-EARED OWL	Asio otus	STRIGIDAE						6				
B273	SHORT-EARED OWL	Asio flammeus	STRIGIDAE						6				

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ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 C FFCCCCFBH P ETETPSSS S
B275	LESSER NIGHTHAWK	Chordeiles acutipennis	CAPRIMULGIDAE	
B277	COMMON POORWILL	Phalaenoptilus nuttallii	CAPRIMULGIDAE	
B282	WHITE-THROATED SWIFT	Aeronautes saxatalis	APODIDAE	
B286	BLACK-CHINNED HUMMINGBIRD	Archilochus alexandri	TROCHILIDAE	
B287	ANNA'S HUMMINGBIRD	Calypte anna	TROCHILIDAE	
B294	LEWIS' WOODPECKER	Melanerpes lewis	PICIDAE	
B296	ACORN WOODPECKER	Melanerpes formicivorus	PICIDAE	
B299	RED-BREASTED SAPSUCKER	Sphyrapicus ruber	PICIDAE	
B302	NUTTALL'S WOODPECKER	Picoides nuttallii	PICIDAE	
B303	DOWNY WOODPECKER	Picoides pubescens	PICIDAE	
B307	NORTHERN FLICKER	Colaptes auratus	PICIDAE	
B323	SAY'S PHOEBE	Sayornis saya	TYRANNIDAE	
B326	ASH-THROATED FLYCATCHER	Myiarchus cinerascens	TYRANNIDAE	
B333	WESTERN KINGBIRD	Tyrannus verticalis	TYRANNIDAE	
B337	HORNED LARK	Eremophila alpestris	ALAUDIDAE	
B339	TREE SWALLOW	Tachycineta bicolor	HIRUNDINIDAE	
B340	VIOLET-GREEN SWALLOW	Tachycineta thalassina	HIRUNDINIDAE	
B341	NORTHERN ROUGH-WINGED SWALLOW	Stelgidopteryx serripennis	HIRUNDINIDAE	
B342	BANK SWALLOW	Riparia riparia	HIRUNDINIDAE	4
B344	BARN SWALLOW	Hirundo rustica	HIRUNDINIDAE	
B348	SCRUB JAY	Aphelocoma coerulescens	CORVIDAE	
B353	AMERICAN CROW	Corvus brachyrhvnchos	CORVIDAE	9
B358	PLAIN TITMOUSE	Parus inornatus	PARIDAE	
B360	BUSHTIT	Psaltriparus minimus	AEGITHALIDAE	
B361	RED-BREASTED NUTHATCH	Sitta canadensis	SITTIDAE	
B362	WHITE-BREASTED NUTHATCH	Sitta carolinensis	SITTIDAE	
B364	BROWN CREEPER	Certhia americana	CERTHIIDAE	
B367	CANYON WREN	Catherpes mexicanus	TROGLODYTIDAE	
B368	BEWICK'S WREN	Thryomanes bewickii	TROGLODYTIDAE	
B369	HOUSE WREN	Troglodytes aedon	TROGLODYTIDAE	
B370	WINTER WREN	Troglodytes troglodytes	TROGLODYTIDAE	
B372	MARSH WREN	Cistothorus palustris	TROGLODYTIDAE	
B375	GOLDEN-CROWNED KINGLET	Regulus satrapa	MUSCICAPIDAE	
B376	RUBY-CROWNED KINGLET	Regulus calendula	MUSCICAPIDAE	
B377	BLUE-GRAY GNATCATCHER	Polioptila caerulea	MUSCICAPIDAE	
B380	WESTERN BLUEBIRD	Sialia mexicana	MUSCICAPIDAE	
B381	MOUNTAIN BLUEBIRD	Sialia currucoides	MUSCICAPIDAE	
B386	HERMIT THRUSH	Catharus guttatus	MUSCICAPIDAE	
B389	AMERICAN ROBIN	Turdus migratorius	MUSCICAPIDAE	
B390	VARIED THRUSH	Ixoreus naevius	MUSCICAPIDAE	
B391	WRENTIT	Chamaea fasciata	MUSCICAPIDAE	
B393	NORTHERN MOCKINGBIRD	Mimus polyglottos	MIMIDAE	

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ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 123456789 FFCCCCFBH ETETPSSS	C P S
B398	CALIFORNIA THRASHER	Toxostoma redivivum	MIMIDAE		
B404	WATER PIPIT	Anthus spinoletta	MOTACILLIDAE		
B407	CEDAR WAXWING	Bombycilla cedrorum	BOMBYCILLIDAE		
B408	PHAINOPEPLA	Phainopepla nitens	PTILOGONATIDAE		
B409	NORTHERN SHRIKE	Lanius excubitor	LANIIDAE		
B410	LOGGERHEAD SHRIKE	Lanius ludovicianus	LANIIDAE		
B417	HUTTON'S VIREO	Vireo huttoni	VIREONIDAE		
B425	ORANGE-CROWNED WARBLER	Vermivora celata	EMBERIZIDAE		
B435	YELLOW-RUMPED WARBLER	Dendroica coronata	EMBERIZIDAE		
B436	BLACK-THROATED GRAY WARBLER	Dendroica nigrescens	EMBERIZIDAE		
B461	COMMON YELLOWTHROAT	Geothlypis trichas	EMBERIZIDAE	6	
B467	YELLOW-BREASTED CHAT	Icteria virens	EMBERIZIDAE	6	
B475	BLACK-HEADED GROSBEAK	Pheucticus melanocephalus	EMBERIZIDAE		
B476	BLUE GROSBEAK	Guiraca caerulea	EMBERIZIDAE		
B477	LAZULI BUNTING	Passerina amoena	EMBERIZIDAE		
B483	RUFOUS-SIDED TOWHEE	Pipilo erythrophthalmus	EMBERIZIDAE		
B484	BROWN TOWHEE	Pipilo fuscus	EMBERIZIDAE		
B494	VESPER SPARROW	Pooecetes gramineus	EMBERIZIDAE		
B495	LARK SPARROW	Chondestes grammacus	EMBERIZIDAE		
B499	SAVANNAH SPARROW	Passerculus sandwichensis	EMBERIZIDAE	3 6	
B504	FOX SPARROW	Passerella iliaca	EMBERIZIDAE		
B505	SONG SPARROW	Melospiza melodia	EMBERIZIDAE	6	
B506	LINCOLN'S SPARROW	Melospiza lincolnii	EMBERIZIDAE		
B509	GOLDEN-CROWNED SPARROW	Zonotrichia atricapilla	EMBERIZIDAE		
B510	WHITE-CROWNED SPARROW	Zonotrichia leucophrys	EMBERIZIDAE		
B519	RED-WINGED BLACKBIRD	Agelaius phoeniceus	EMBERIZIDAE		
B520	TRICOLORED BLACKBIRD	Agelaius tricolor	EMBERIZIDAE	6	
B521	WESTERN MEADOWLARK	Sturnella neglecta	EMBERIZIDAE		
B522	YELLOW-HEADED BLACKBIRD	Xanthocephalus xanthocephalus	EMBERIZIDAE		
B530	HOODED ORIOLE	Icterus cucullatus	EMBERIZIDAE		
B532	NORTHERN ORIOLE	Icterus galbula	EMBERIZIDAE		
B543	LESSER GOLDFINCH	Carduelis psaltria	FRINGILLIDAE		
B545	AMERICAN GOLDFINCH	Carduelis tristis	FRINGILLIDAE		
B546	EVENING GROSBEAK	Coccothraustes vespertinus	FRINGILLIDAE		
M001	VIRGINIA OPOSSUM	Didelphis virginiana	DIDELPHIDAE		
M018	BROAD-FOOTED MOLE	Scapanus latimanus	TALPIDAE		
M023	YUMA MYOTIS	Myotis yumanensis	VESPERTILIONIDAE		
M028	CALIFORNIA MYOTIS	Myotis californicus	VESPERTILIONIDAE		
M032	BIG BROWN BAT	Eptesicus fuscus	VESPERTILIONIDAE		
M033	RED BAT	Lasiurus borealis	VESPERTILIONIDAE		
M034	HOARY BAT	Lasiurus cinereus	VESPERTILIONIDAE		
M037	TOWNSEND'S BIG-EARED BAT	Plecotus townsendii	VESPERTILIONIDAE	6	

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ID	SPECIES NAME	SCIENTIFIC NAME	FAMILY	STATUS 1 FE	2 FT	3 CE	4 CT	5 CP	6 CS	7 FS	8 BS	9 H	CPS
M038	PALLID BAT	Antrozous pallidus	VESPERTILIONIDAE						6				
M039	BRAZILIAN FREE-TAILED BAT	Tadarida brasiliensis	MOLOSSIDAE										
M045	BRUSH RABBIT	Sylvilagus bachmani	LEPORIDAE						6			9	
M047	DESERT COTTONTAIL	Sylvilagus audubonii	LEPORIDAE									9	
M051	BLACK-TAILED HARE	Lepus californicus	LEPORIDAE									9	
M072	CALIFORNIA GROUND SQUIRREL	Spermophilus beecheyi	SCIURIDAE										
M081	BOTTA'S POCKET GOPHER	Thomomys bottae	GEOMYIDAE										
M087	SAN JOAQUIN POCKET MOUSE	Perognathus inornatus	HETEROMYIDAE						6				
M105	CALIFORNIA KANGAROO RAT	Dipodomys californicus	HETEROMYIDAE						6				
M112	BEAVER	Castor canadensis	CASTORIDAE										
M117	DEER MOUSE	Peromyscus maniculatus	CRICETIDAE						6				
M134	CALIFORNIA VOLE	Microtus californicus	CRICETIDAE	1		3			6				
M139	MUSKRAT	Ondatra zibethicus	CRICETIDAE									9	
M140	BLACK RAT	Rattus rattus	MURIDAE										
M141	NORWAY RAT	Rattus norvegicus	MURIDAE										
M145	PORCUPINE	Erethizon dorsatum	ERETHIZONTIDAE										
M147	RED FOX	Vulpes vulpes	CANIDAE				4			7	8		
M158	MINK	Mustela vison	MUSTELIDAE									9	
M160	BADGER	Taxidea taxus	MUSTELIDAE						6			9	
M163	RIVER OTTER	Lutra canadensis	MUSTELIDAE						6				
R022	WESTERN FENCE LIZARD	Sceloporus occidentalis	IGUANIDAE										
R029	COAST HORNED LIZARD	Phrynosoma coronatum	IGUANIDAE										
R036	WESTERN SKINK	Eumeces skiltonianus	SCINCIDAE										
R037	GILBERT'S SKINK	Eumeces gilberti	SCINCIDAE										
R039	WESTERN WHIPTAIL	Cnemidophorus tigris	TEIIDAE										
R040	SOUTHERN ALLIGATOR LIZARD	Gerrhonotus multicarinatus	ANGUIDAE										
R048	RINGNECK SNAKE	Diadophis punctatus	COLUBRIDAE										
R051	RACER	Coluber constrictor	COLUBRIDAE										
R052	COACHWHIP	Masticophis flagellum	COLUBRIDAE										
R053	CALIFORNIA WHIPSNAKE	Masticophis lateralis	COLUBRIDAE										
R057	GOPHER SNAKE	Pituophis melanoleucus	COLUBRIDAE										
R058	COMMON KINGSNAKE	Lampropeltis getulus	COLUBRIDAE										
R060	LONG-NOSED SNAKE	Rhinocheilus lecontei	COLUBRIDAE										
R061	COMMON GARTER SNAKE	Thamnophis sirtalis	COLUBRIDAE										
R062	WESTERN TERRESTRIAL GARTER SNAKE	Thamnophis elegans	COLUBRIDAE										
R063	WESTERN AQUATIC GARTER SNAKE	Thamnophis couchi	COLUBRIDAE										
R071	NIGHT SNAKE	Hypsiglena torquata	COLUBRIDAE										
R076	WESTERN RATTLESNAKE	Crotalus viridis	VIPERIDAE										

TOTAL SPECIES: 184

Status Definitions:

1. FE: Federally Endangered
2. FT: Federally Threatened
3. CE: California Endangered
4. CT: California Threatened
5. CP: California Protected
6. CS: California Special Concern
7. FS: Forest Service Sensitive
8. BS: BLM Sensitive
9. H : Harvest

CPS: Candidate or Proposed Candidate Species

APPENDIX B

AGWATER SUMMARY

APPENDIX B

ON-FARM WATER MANAGEMENT

AGWATER RESULTS AND NARRATIVE SUMMARY

The AGWATER irrigation computer program was used to provide a "snapshot" of current on-farm water management practices and performances within the boundaries of the study area. AGWATER is a diagnostic tool, not a predictive tool. Information used in the program was provided by the growers. These results should not be used to statistically represent conditions in the district as only ten growers were interviewed.

The following were the primary objectives:

1. Get an idea of the magnitude of runoff and deep percolation.

2. Achieve an understanding of typical practices such as irrigation scheduling and systems operations.

3. Get an idea of the magnitude of shallow ground water uptake by crops.

4. Identify typical opportunities for improvement if reducing runoff and deep percolation and improving the root zone moisture environment are needed.

Sprinkler Irrigated Tomatoes

All four sprinkler evaluations were in areas of very shallow water tables. Shallow water table refers to water levels at one to four feet below the ground surface. Growers indicated that the higher level of control provided by sprinklers over furrow irrigation is necessary to prevent water logging when working with a high water table.

Although the evapotranspiration (Et) rate for tomatoes is 23 inches, the growers applied only 13 to 17 inches. Growers indicated that yields are comparable to other non-water table areas. This suggests that six to 10 inches of crop Et is met through uptake from the water table.

Growers indicated there is little or no runoff from sprinkler irrigated fields. The grower's irrigation scheduling decisions, such as when to irrigate and how much to apply, were about as good as could be expected for the first two or three irrigations. Scheduling decisions could not be evaluated for later irrigations because AGWATER is not capable of tracking uptake from shallow water tables.

Opportunities exist to reduce deep percolation by improving system distribution uniformities (DU). DU's ranged from 58 to 69 percent. Uniformities could be increased to about 75 percent if alternate sets are used and pressure losses along the wheel lines are reduced. Switching to lower flow nozzles should be considered to reduce pressure losses.

Furrow Irrigated Tomatoes

All four furrow evaluations were in areas with no water tables within the root zone. The growers evaluated were infiltrating about five inches of water with each irrigation. During the first two or three irrigations the soil could only hold one to two inches. It is typical of surface irrigation systems that amounts of water under three inches are difficult to apply uniformly. Additionally, it appears that some of the irrigations could have been delayed several days, which would have provided for more water storage when irrigations are applied. This resulted in significant deep percolation of 12 to 21 inches for the season.

Season-long runoff ranged from zero inches, when on a tailwater recovery system was used, to six to 12 inches from the other fields. One grower described the necessity to "runby" or not apply up to 25 percent of the water delivered to him during certain periods. Another grower indicated his desire to be able to cutback furrow flow rates after the water advances to the end of the field to reduce runoff.

With the exception of one field, DU's were fair to good, averaging 75 percent. There is not much room for improving uniformities on the evaluated furrow systems.

Excessive deep percolation can be reduced significantly by using sprinklers to apply smaller amounts of water during the early developing root zone period and switching to furrow irrigation later when adequate soil water storage is available. Soil moisture monitoring or climate based crop water use irrigation scheduling methods can improve irrigation timing decisions. It's likely that one early season irrigation could have been eliminated on two of the fields evaluated.

Beans

Only two bean fields were evaluated. One was furrow irrigated, the other furrow irrigated followed by sprinkler irrigation. On the furrow only field the average seasonal deep percolation was seven inches, runoff was 14 inches, and DU was 90 percent. Deep percolation and runoff could be reduced significantly if sets are shortened. Lower flow rates, allowing for a small reduction in DU, would reduce the volume of runoff.

Case Studies

Two case studies of tomato crops, one furrow irrigated, the other sprinkler irrigated, are presented to represent the "typical" practices used to grow this crop.

'Table : Tabular Summary of Agwater Evaluations and Grower Interviews.

Tomatoes

Irrigation Method	ET Inches	Applied Inches	Runoff Inches	Deep Perc. Inches	DU percent	Irr. Eff. percent	Comments
Sprinkler	23	13	0	1.5	61	1/	First irr. too soon, others scheduled well, high table apparently supplying significant water to meet
Sprinkler	NA	17	0	2.3	67	1/	First 2 irr. run about twice as long as needed, timing good, high water table apparently suppling 5" to ET.
Sprinkler	23	13	0	1	69	1/	Scheduling very good, 10"+/– water from w.t. or sig. yield loss,
Sprinkler	24	13	0	1	69	1/	W.T. at 1–3', apparently sig. w.t. uptake, good scheduling.
Furrow	23	41	6	17	75	40	Too much water 1st 2 irr., could have waited longer before 2nd and 3rd irr., runby (25% of last irr. deliver) indicated as a problem by grower
Furrow	22	43	12	12	77	31	Could have waited longer before 2nd irr., amounts high but timing good on 3 and 4 irr. a little late on 5 and 6. He would like to be able to use cutbacks to reduce runoff.
Furrow	22	51	12	21	75	30	First 3 irr. too early, furrow irr. can't efficiently apply small amounts (<3 inches).
Furrow	22	22	0	12	65	40	First irr. too early, applied 5 – needed 1, difficult to apply less than 3" efficiently significant apparent crop stress (under irr.), end of season, no w.t.

Beans

Irrigation Method	ET Inches	Applied Inches	Runoff Inches	Deep Perc. Inches	DU percent	Irr. Eff. percent	Comments
Furrow	22	30	14	7	90	NA	Sets were too long. They can be reduced. Apparent crop stress.

Melons

Typically preirrigated only. About 9–12 " applied with 25 to 50 percent or more drained from the surface (runoff) to prepare seedbeds. Crop survives off of stored soil water onl

95 percent of all melons in the area grown this way.

Rice (Grower Comments)

Some "heavy" soils deep perc. a lot of water. The use of small "light" dikes encourages more requests for emergency water releases.

Some rice fields with clay (112) soil will take 11 ac–ft/ac water to grow a crop.

He runs a "little" over the last weir. "Nothing like they used to." He applies an average of 8 feet of water. Seepage does occur!

1/ Irrigation Efficiencies could not be calculated due to water table contributions to ET.

NA Not Available
ET Evapotranspiration

RD 1500 Case Study: Tomatoes, Furrow Irrigated

Setting: Water Table deeper than 6ft. throughout the season
Soils -- silt loam
40 acre field

Crop: Plant emergence -- April 1st
Harvest -- Aug. 10

Irrigation Practices: Every furrow irrigated during each set
Flow rate delivered to field -- 3 cfs (1346 gpm)
Flow to each furrow cutback (reduced) after water reaches end of field

Irrigation Date	Set time (hours)	Applied (inches)	Runoff (inches)	Soaked in (inches)	Used by Crop (inches)	*Deep perc. (inches)
4/17	24	6.2	0.9	5.1	0.7	4.9
5/17	48	8.9	1.2	7.3	1.7	6
5/30	24	5.4	0.7	4.4	1.8	2.6
6/13	24	5.4	0.7	4.4	2.9	1.5
6/27	24	5.4	0.7	4.4	4	0.3
7/11	12	5.4	1.5	3.6	4.3	0
7/18	6	4.5	0	4.2	2.1	1.4
Harvest					4.9	
Totals		41.2	5.7		22.4	16.7

* Irrigation water which moves below the rootzone and is not available for crop use.

RD 1500 Case Study: Tomatoes, Sprinkler Irrigated

Setting: Water Table at 2 to 3 ft. throughout the season
Soils – clay
80 acre field

Crop: Plant emergence – May 8th
Harvest – Sept. 7

Irrigation Practices: Alternate sets are NOT used
Nozzle size – 3/32
Difference in sprinkler pressure down the wheel line – 17 psi

Irrigation Date	Set time (hours)	Applied (inches)	Used by Crop (inches)	2/ Deep perc. (inches)	3/ Distribution Uniformity %
5/1	9	1.3	0.2	1.2	58
5/4	7	1	0.5	0.4	58
5/7	6	0.9	0.6	0.3	58
5/30	9	1.3	1.9	0	58
6/15	14	2.1	1.8	0	56
6/26	14	2.1	1.6	0	56
7/7	15	2.2	2.2	0	58
7/18	13	1.9	1/ 2.8	0	58
Harvest			1/ 12.3		
Totals		12.8	23.8	1.9	

1/ Assume difference between irrigation applied and water needed by crop is made up from the water table.
2/ Irrigation water which moves below the rootzone and is not available for crop use
3/ Relatively poor distribution uniformity caused by not useing alternate sprinkler sets and a relatively large pressure difference along the wheel line.

APPENDIX C

CALCULATIONS APPENDIX

SAMPLE CALCULATIONS FOR WATER CONSERVATION MEASURES

Distribution Control Systems

There are many options for modification of the existing irrigation ditch system. These include pipelines, canal level control structures, regulating reservoirs, lining for canals and reservoirs, modification of the drainage system to increase recirculation or a combination of these options. The ideal combination would either provide water to the system at a lower cost than present or provide water when deliveries are reduced. This solution would not negatively impact fish and wildlife resources, and would maintain the salt balance in the district. Unfortunately, none of the options examined would provide water at a cheaper cost than the present system. They all increase net operating costs for the water users. These systems will make more water available in the service area during short water years.

Calculations were based on data obtained from District and Company records and the Soil Survey; permeability was estimated using the Unified Soil Classification system and the Civil Engineering Standard Desk Reference by McGraw Hill; typical costs for equipment were obtained from distributors; channel dimensions were obtained from Company employees; and costs for concrete, excavation, and other work was estimated using contract costs from other projects.

Ditch Lining Option

The Company billed its customers for approximately 144,000 acre-feet of water in 1993. BOR and Company records show that about 184,000 acre-feet were diverted from the Sacramento River in 1993. This difference was assumed to be lost to seepage in the ditch system. Leakage is a function of wetted surface area, soil permeability, and water depth. Concrete is not an impermeable membrane and a CH or CL soil material has about one-half the permeability as a concrete lining. The Unified Soil type of the irrigation ditch system (Figure 3) was overlaid on the Soil Survey maps. The length of each soil type was measured, the channel dimensions and depths for that reach were used to calculate mean depth and wetted areas. It was assumed that the ditch system was full for the entire irrigation season. The calculation for water loss is:

$$Q = k\,A\,h\,t$$

In this equation "k" is the permeability factor in feet per second per foot of head, "A" is the wetted area in square feet, "h" is the mean distance between the ditch centroid and the water table, and "t" is time in seconds. This equation calculates a flow in cubic feet per second for the ditch section. This calculation was done for the Company ditch system. The results gave an estimate for leakage potential for the entire system in acre-feet after dividing the total 43,560 cubic feet per acre-foot. The results of this calculation was an estimated leakage for the irrigation season of approximately 41,600 acre-feet. This was in good agreement with the estimated loss from the system for 1993 after factoring in an average daily evaporation loss from the ditch surface of 0.25 inches per day.

All soils other than the CH and CL soils were expected to be lined and the k factor of 0.0000001 feet per second was used. The leakage was recalculated and compared with the initial leakage estimate for each section. The difference was the estimated water savings for each lined reach. A four-inch layer of concrete was assumed for each treated section covering the wetted perimeter. It is possible to reduce the cross section with concrete but the earthfill and compaction would have increased the cost beyond the estimated lining of the entire section. The cost of lining was estimated to be $150 per cubic yard of concrete assuming a neat line section.

Volume of Concrete = A * 4 inches/ 12 inches * 1 cubic yard/ 9 cubic feet

"A" is the wetted perimeter of the channel multiplied by the section length and is in square feet.

The volume of water saved was divided by the cost of the concrete lining to estimate the installation cost per acre-foot of leakage reduced. The length of the three groups were 4.5 miles, 29.8 miles, and 0.75 miles, respectively. Approximately 125 miles would not need to be lined. If the first group lining was installed it would reduce seepage loss by about 19,000 acre-feet. If the entire 34.4 miles were lined the ditch seepage would be reduced approximately 37,000 acre-feet. The expected 10-year life of the lining was used for development of the operation and maintenance costs. It was expected that the system would be fully replaced in its design life. An interest rate of eight percent was used for amortization. The amortization factor for a ten-year life at an eight percent interest rate is 0.14903. This results in a $17, $88, and $117 per acre-foot cost for each acre-foot of seepage reduced for each class of ditch.

The estimated project installation cost for the 4.5 mile option, and 34.4 mile option are $2.3 million and $12.8 million respectively.

The calculation for pipeline replacement was assumed to be an equivalent concrete lined section for the entire ditch system and multiplied by 1.5 for other costs. The design life for the pipeline system was estimated to be 25 years and the maintenance cost was estimated to be $1,500 per mile. The project installation cost was estimated to be $75 million dollars.

Modification of the canal system to spill water back into the Sacramento River or into a regulating reservoir. The canal gates would need to be placed into concrete sections which the manufacturer (Waterman AVIS gates) estimates would cost the same as the gate. The estimated cost for the canal modification would be $4.7 million dollars for the 82 gates. Without the installation of a regulating reservoir there would be no net water savings. The regulating reservoir(s) would cost about $1 million dollars. The combined project would cost $5.7 million dollars. There is no estimate available for uncontrolled spills, which makes it impossible to estimate a price for each acre-foot of water saved.

Basin Wide Recirculation System

The preliminary design of a recirculation system which would move drainage and tail water upslope into the main canal would need to lift approximately 50 cfs from the Bohanan Dam at mile 7.5 to the canal at mile 19.5.

Presently the District and farmers recirculates a total of 30,000 to 32,000 re-feet of drainage water in short years. The volume discharged at Karnak during the 1994 irrigation season was 71,000 acre-feet. The District estimates that 80 percent of this drainage water is generated upstream of Bohanon Dam. If the system is designed to recirculate this back to the main canal this would be a maximum volume of 320 cfs as a design discharge in addition to the present recirculation capacity of the system.

If the discharge record for 1993 is used to estimate the amount of water which could have been recirculated in the system the total volume for July and August of 1994 is 24,655 acre-feet. The average discharge from Karnak would have been 50 cfs or 6,149 acre-feet. The drainage discharge to the Sacramento River during July and August would have an average EC of 2,263 and 2,215 micromhos/cm, respectively, if the salt discharge was held constant.