A PRELIMINARY PLAN FOR THE MANAGEMENT OF WATER AND SALT FLOWING INTO THE SAN JOAQUIN RIVER FROM THE DRAINING ENTITIES ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY

by

William R. Johnston
Search II

and

Gerald T. Orlob
G. T. Orlob and Associates

Prepared for

SOUTH DELTA WATER AGENCY
504 Bank of Stockton Building
311 East Main Street
Stockton, CA 95202

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INTRODUCTION

The Problem

Periodically during normal water years and frequently during dry or critical water years, the quality of the San Joaquin River water does not meet water quality objectives established to protect the beneficial uses of the water. The quality of the River water is particularly important to agricultural water users that have rights to use water from the San Joaquin River. Studies of the River indicate that a substantial portion of the salt and other constituents in the river come from the west side valley soils with shallow saline water tables where subsurface drains have been installed to control the water tables in the irrigated agricultural land. Some of the salt is applied in the irrigation water and some of it is native to the west side soils. The water produced by the subsurface agricultural drains flows to the San Joaquin River through Mud and Salt Sloughs. This report explains the problem and recommends a management plan for controlling the flow of salt and water from the drains to the river.

The Area

The drainage problem area is in Western Fresno and Merced Counties, approximately between Mendota, on the south, and Gustine, on the north. It includes land in the Firebaugh Canal Water District, Broadview Water District, Panoche Water District, Pacheco Water District, Charleston Drainage District, Central California Irrigation District and intervening irrigated land. This is the area that drains both subsurface drainage water and surface water (tailwater) runoff into the main drain of the Central California Irrigation District below Russell Avenue, the Hamburg Drain, the Panoche Drain and the Charleston Drain and is called the "area of the draining entities".

[1] Prepared by William R. Johnston, Search II, and Gerald T. Orlob, G.T. Orlob & Associates, for South Delta Water Agency, May 1993.

DISCUSSION

San Joaquin River Water Quality

There has been an increase in the salinity of the San Joaquin River water since the Delta Mendota Canal went into operation, about 1951. The increase in salinity of the river has been substantial during the past several years. Two main reasons for this salinity increase are: first, there has been an increase in the salinity of drainage water reaching the river (much of which comes from subsurface drainage systems in the area of the draining entities) because there have been changes in the drainage water flow patterns through the Grasslands Area and second, there has been an escalation in reuse of the rather good quality tailwater by individual water users. Good quality tailwater was heretofore mixed with saline subsurface drainage water prior to its flowing through the Grassland Area and into the river.

This change was escalated during the 1986-1992 drought. It should be noted, that if all of the tailwater generated by these draining entity districts is ever completely recycled, the salinity and the concentration of other constituents in the water draining into the San Joaquin River from these districts will increase even higher.

In addition to the effects of the drought, other factors contributing to poor San Joaquin River water quality are:

1) competition for California's water supplies between metropolitan areas, fish and wildlife interests and agriculture needs, and

2) political pressure applied by environmental groups and others to force agricultural water users to "conserve" water.

Even without the pressure of the drought and environmental groups, it is believed that the draining entities will eventually have to require their water users to recycle as much tailwater as possible. The limited capacity of the existing open drainage system available to remove water from district lands will be a major factor in causing this to happen. The cost of operating a district system that could handle all of the tailwater produced under conditions of a full water supply and without any controls will be too high for economic operation. Moreover, it would be impossible to operate viable agriculture if there is no place to discharge the drainage water. In addition, individual agricultural water users probably will not want to lose the potential for use of tailwater as the cost of their water supply continues to increase.

Another significant reason for past increases in salt load is the increase in the amount of land drained with subsurface drainage systems. The area within the draining entity districts served by subsurface drainage systems increased from about 18,700 acres in 1965 to about 58,500 acres in 1991. As additional subsurface drains were installed, the inevitable result was the production of additional saline drainage water that reached the San Joaquin River and contributed to the degradation of the river water quality.

When the selenium-wildlife problem was discovered in the Grassland Area several years ago, the wetlands area water managers began refusing to accept the saline drainage water to flood wetlands and instead diverted this drainage water directly to the river. Also, during the past few years the timing of flooding and draining the wetlands has been modified. All of these factors have contributed to the degradation of quality in the San Joaquin River water.

<u>State and Federal Policies</u>

A number of "potential solutions" of the West Side San Joaquin Valley drainage problem have been discussed and studied over the years. Most recently the coordinated State and Federal San Joaquin Valley Drainage Program issued a December 1991 Report entitled "A Strategy for Implementation of the Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley". This report specified eight major components of a "solution" to manage saline drainage water within the drainage problem area. The components include:

1) Source control (irrigation water conservation),
2) Drainage water reuse,
3) Evaporation,
4) Land retirement,
5) Ground water management, (groundwater pumping),
6) Institutional changes,
7) Substitute water supplies for fish and wildlife, and
8) Discharge to the San Joaquin River.

Desalinization and drainage water injection into deep aquifers are two other options that have also been studied, but were not recommended for implementation in the Drainage Program report. Every suggested management option has its own unique environmental, economical, physical and/or political problem regarding implementation and none really lead to a "solution". Even if the "drainage problem" cannot be solved in total, action must be taken to minimize damage to fish and wildlife and to agricultural land, and to reduce or eliminate the impact of the production of saline drainage water on the quality of water in the San Joaquin River. A program must be implemented that is physically achievable and will not cause adverse salt build up in the drained soils that would be adverse to agricultural production.

The State Water Resources Control Board is also attempting to improve the situation. In 1988, the Board adopted a Non-point Source Management Plan that outlines general management approaches that are scheduled to be applied to agricultural discharges. These management approaches are designed to achieve performance goals or objectives.

Data Review

During the past six years the Central Valley Regional Water Quality Control Board, the US Geological Service, Summers Engineering, and others have collected a large amount of data pertaining to the production of salt and water in the draining entities located up slope from the Grasslands Area, the routing and flow of the salt and water through the Grassland Area and the discharge of the same into the San Joaquin River. The data are a result of a significant coordinated monitoring program by the draining entities and the Regional Board. Charles M. Burt, et al. (August 1992) has compiled information on drainage water management by the draining entities in a report entitled "Irrigation and Drainage in the Grassland Area of the Westside of the San Joaquin Valley" and the Regional Board has prepared annual reports under its agricultural drainage investigation program, entitled "Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis" and "Agricultural Drainage Contribution to Water Quality in the Grassland Area of Western Merced County, California". These reports provide basic information on the impact of the production of subsurface agricultural drainage water on the Grassland Area and the San Joaquin River.

Additionally, the South Delta Water Agency has sponsored development of a comprehensive data base of hydrologic and water quality data for the San Joaquin River System from Friant Dam to Vernalis. Included data have been derived from USGS water supply papers, monitoring records of the U.S. Bureau of Reclamation, California Department of Water Resources, Central Valley Regional Water Quality Control Board, and from specific studies by those agencies and others. The data base covers the period 1930 to 1992.

It has been estimated from various sources available for this preliminary study that between 1987 and 1989, the proportionate amount of drainage flow from the draining entities originated approximately as follows:

DISTRICT	PERCENT
Broadview	15.0
Panoche	41.9
Pacheco	8.3
Charleston	6.3
Firebaugh	18.9
Central California	5.5
Poso	4.2
Total	100.0

These data indicate that between 1987 and 1989, over 75 percent of the drainage flow from the drainage problem area originated from the Broadview, Panoche and Firebaugh Districts.

Joe Karkoski, US Environmental Protection Agency staff person, assigned to the Central Valley Regional Water Quality Control Board to study San Joaquin River water quality problems, has developed a data set based on U.S. Geological Survey continuous salinity measurements, filled in with data collected by the Regional Water Quality Control Board, and USGS flow measurements. These data show the monthly discharges of water and salt from the drainer's land that ends up in Mud and Salt Sloughs and subsequently in the San Joaquin River. Tables prepared by Karkoski are appended hereto. They show the monthly flow in acre-feet and salt discharge in tons from Salt Slough and Mud Slough and the percentages of water and salt coming from the drainers land. The tabulated data show that the monthly salt load from the drainers ranges from 18 percent (December 1985) to 91 percent (July 1991) of the total salt load discharged through Salt and Mud Sloughs into the San Joaquin River.

RECOMMENDED MANAGEMENT PLAN

Modification of Subsurface Drainage Systems

Currently almost 60,000 acres within the draining entities have on-farm subsurface drainage systems. Assuming that roughly about 0.5 acre-feet per acre of subsurface drainage water is produced by each acre with on-farm drains, then about 30,000 acre feet of subsurface drainage water can be expected to be produced each normal water year.

During drought years when water deliveries to the drainage problem area are curtailed, less drainage water will be produced. Some of the saline drainage water produced in the area is currently recycled within the drainage problem area. Much of it, however, finds its way to the San Joaquin River.

There are basically only two ways in which this drainage water can be managed once it is produced. One is with surface storage facilities, i.e. with open ponds within the area, and the other is by removing it from the area where it is produced, ie. draining it to the ocean. The first is environmentally unacceptable because it is not known how long salt laden water containing other constituents, such as selenium, would have to be stored in open ponds, particularly during drought situations. Additionally, this solution imposes a burden on the agricultural sector since it requires dedication of otherwise productive land to on-farm retention ponds.

The second, a drain to the ocean, while the most scientifically feasible solution, continues to be politically unacceptable. It is believed that an economical process to remove selenium from drainage water may eventually be available for application. The technology is already developed. If this approach becomes both technically and economically feasible, the situation regarding evaporation ponds and the use of the drainage water for fish and wildlife habitat may change significantly. However, until then something must be done to protect the San Joaquin River.

Under current environmental constraints, economical circumstances and political reality the most reasonable method of controlling the production of the subsurface drainage water and its subsequent flow to the San Joaquin River is to retain the water in the ground where the subsurface drainage systems are located. Redesign of the drainage facilities and control of flows would allow retention of saline water in the ground until it could be safely moved to the San Joaquin River, where at an appropriate release time it could then be diluted with high flows and transported down the river to the Bay and Ocean with lesser impact on downstream water users.

This scheme has the potential to meet the alternative "Controlled and limited discharge of drainage water from the San Joaquin Basin portion of the study area to the San Joaquin River, while meeting water quality objectives" as discussed in the December 1991 Report of the San Joaquin Valley Drainage Program. Modification of subsurface drainage systems is physically possible, but will require that most of the subsurface drainage systems within the draining entities be either reconstructed or replaced with systems that would allow, with good irrigation water management, the prevention of the shallow saline groundwater levels from surfacing or rising into the crop root zone for extended periods of time. It is estimated that this could cost up to $1,000 per drained acre or as much as $60,000,000 if the approach is adopted for the entire area.

Although initially costly, this solution could be considered as permanent, allowing:

1) control of production of saline drainage water,

2) regulation of discharge of poor quality water to the San Joaquin River,

3) compliance of the draining entities with all San Joaquin River water quality objectives, and

4) access by all downstream water users to good quality water.

As noted, careful on-farm water management would be necessary to properly control high water tables and achieve salt balance within the crop root zone. This solution would not, however, assure total salt balance for the irrigated land on the west side of the Valley unless sufficient dilution flows are assured during critical and dry water years. Coordination of west side drainage flows with the release of water from the Eastside tributaries would be a necessary part of the ultimate water quality management plan.

ANALYSIS OF THE MANAGEMENT PLAN

Model Analysis

For the purposes of assessing the merits of the proposed solutions to the salinity problems of the San Joaquin River the South Delta Water Agency has sponsored the development and application of a new salt balance computer model to be applied to the main stem of the river from Mendota to Vernalis. The model, identified as SJRMOD, is designed primarily to assist in evaluation of alternative management strategies to regulate the accretion of salts (total dissolved solids, TDS) from the west side of the San Joaquin Valley. However, it is expected to have general utility in the assessment of any alternative concerned with regulation of runoff and quality along the course of the river.

SJRMOD provides a means of simulating the seasonal patterns of flow and water quality along the river and at specific locations between Mendota and Vernalis. Changes in salt load and TDS concentrations resulting from alternative control options can be estimated with the model. Comparisons can be made of flows and qualities resulting from alternative salt load control options, and these can be contrasted with historic conditions that are known to have resulted in poor water quality.

A goal of the model's application would be to devise the best possible plan for management of the salt load in the San Joaquin River. In addition to evaluation of salt load control alternatives, the model provides a means of exploring other control measures, such as regulating flows below impoundments on the east side of the valley or augmenting water quality control releases from reservoirs like New Melones that have provisions for storage of water for quality control.

At its present level of development SJRMOD represents a prototype system comprised of eight river reaches (although more can be included) extending from the vicinity of Mendota to Vernalis (See Figure 1). River reaches are bounded by junctions of the main stem and tributaries, and by stream gaging or monitoring stations along the river. The model is designed to simulate flow and quality at selected time steps (initially monthly) for time series of any duration. Data requirements are historical or synthetic time series of flows and qualities of principal tributaries and drainage loads.

A set of assumptions derived from experience with the operation and performance of subsurface drainage systems draining into the Grasslands area of the west side of the valley provide a starting point for the development of a practical salt load control plan. These include estimates of quantities and qualities of drainage return flows from irrigated lands that normally reach the San Joaquin River through Mud and Salt Sloughs. The general arrangement of the model is illustrated in the sketch in Figure 1, showing the San Joaquin River, its principal tributaries, and the locations of gaging stations and local drainage returns.

Alternative control measures to regulate contributions of salt from these sources to the river are currently being explored with the aid of SJRMOD, beginning with an alternative along the lines of the Preliminary Plan discussed herein. To test the concept of salt load retention during a sequence of dry years it was considered practical to use a historical time series based on actual observations. Three drought years 1989, 1990, and 1991 were selected for this test.

Complete hydrologic records were available for all three years at all key gaging stations in the study area, including the flows from Salt and Mud Sloughs. Additionally, electrical conductivity records from continuous recorders at key monitoring locations were available for 1989 at all stations, and for 1990 and 1991 at all stations but Newman. The Newman 1990-1991 time series of EC was developed using a correlation relationship developed at both Newman and Salt Slough for 1989.

RESULTS

In preliminary studies to test the model two different case studies were examined. These studies involve shifting discharges only on a calendar basis. Greater benefits might be expected from a future more controlled management of discharges to coincide with water available dilution flows.

Case 1. Seasonal Management of Salt Load

For Case 1 the following assumptions were made:

1) One half of the salt load from Mud and Salt sloughs were retained, i.e. stored within the land with subsurface drainage systems tributary to the sloughs, during the April-September irrigation season.

2) Retained drainage (volumes and associated salt load) was released to the river at the mouth of the sloughs during the succeeding non-irrigation season, October through March, in amounts equal to one sixth of the total retained in the previous six-month period.

3) No salts were returned to the river during the first half of 1989 (October through March of the hydrologic year ending in 1989).

4) All flows and qualities of tributary streams were as historically recorded for the period October 1988 to September 1991 (three successive water years).

Results of the analysis for Case 1 are presented in Figures 2 and 3. These figures show typical results of simulations using SJRMOD, depicting the three year patterns of runoff (acre feet per month) and salinity (milligrams per liter) for the San Joaquin River at Vernalis. Results of two simulations are depicted in each figure, one for unregulated conditions and another for regulated salt load retention and release as outlined above. Flows are presented as monthly runoff in 1,000 acre feet. Qualities of flows are expressed in milligrams per liter of total dissolved solids (TDS) derived from direct observations of electrical conductivities (EC) in the San Joaquin River and its principal tributaries, or as calculated by SJRMOD. TDS values (mg/l) were computed from reported EC measurements (microSiemans/cm) by multiplying a factor of 0.6. The horizontal axis in each figure corresponds to the simulation period October 1988 to

September 1991 for the three water years, 1989, 1990 and 1991.

Figure 2 shows the change in patterns of runoff at Vernalis (Reach 1 in SJRMOD) resulting from retention of 50 percent of the irrigation season flow from Salt and Mud Sloughs and its reallocation during the succeeding wet weather period, October through March. Flow reductions at Vernalis during the April to September period due to reduced flows from Salt and Mud sloughs are seen to be relatively minor in this case, compared to historic experience, due to the dominance of tributary inflows downstream of the sloughs. Retention of drainage water resulted in reducing flows at Vernalis by 7 to 16 percent during the irrigation season. On the other hand, on the succeeding wet periods flows would be increased by 9 to 13 percent above the historic (unregulated) levels by the return of retained drainage, as considered in this management alternative.

The consequences of these changes in terms of water quality are presented in Figure 3, where reductions in TDS concentrations at Vernalis during the irrigation season are seen to range from 40 to 130 mg/l, i.e., 9 to 30 percent of historic concentrations during the three year period. This result represents an important improvement in the river water quality at Vernalis, sufficient in this example to insure maintenance of TDS levels below the target level of 500 mg/l throughout most of the irrigation season.

While the 500 mg/l target was exceeded 10 of the 18 months during the three seasons depicted, the target was exceeded only in 4 months under the seasonal salt management program. The mean TDS concentration for the 18 months of irrigation season simulated in this case study was reduced from 519 mg/l for the historic unregulated condition to 426 mg/l for the condition of regulated drainage.

The substantial benefit of salt load management is clearly evident in this example. However, it is important to note also that substantial releases of high quality water from New Melones Reservoir that actually occurred during this period contributed significantly to improvement of the quality of water in the river at Vernalis. An attractive management strategy could include both salt load management and, if available, additional managed water quality releases from upstream storage.

Case 2. Planned Management of Salt Load

If physical regulation of subsurface drainage flows can be achieved, it should be possible to retain the poorest quality contributions of drainage flows to Salt and Mud Sloughs during the irrigation season and, likewise, to release the retained drainage flows and salt loads at times when the dilution potential of the San Joaquin system is the greatest, i.e. to schedule the releases. This case study is designed to demonstrate the potential of such a program of planned management of salt load on the quality of the water in the San Joaquin River at Vernalis.

The assumptions under which SJRMOD was used to simulate the effects of a specific release schedule are as follows:

1) The actual flows and qualities of tributaries and intermediate gaging or monitoring stations are used in the model, just as in Case Study 1.

2) Salt load retention is assumed to be practiced during the months of March and May through September.

3) No retention of salt load occurs during April, rather releases are made in the amount of 10 percent of the annual retained salt load to coincide with expected "pulse flows" from the east side tributaries and the draining of wetlands which are to be made to enhance Chinook Salmon smolt outmigration.

4) Drainage releases to the river are assumed to occur during the period October through February, with 5 percent of the annual retained load released in each of October and November and 26.7 percent in each of December, January and February, which are heavy preirrigation months in the drained area.[2]

Results of the analysis for Case 2 are presented in Figures 4 and 5. These figures are similar to Figures 2 and 3 for Case Study 1 and show some differences due to changing the time of retention and time of release of the salt load in a more managed scheme. As one might expect there is not a great deal of difference between the two cases examined. Except for a few months, the results show only a slight improvement with Case 2 over Case 1. This may be due to the fact that a sequence of dry years was selected for evaluation, so the benefits are large (in terms of improving river water quality during the irrigation season) in both instances.

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[2] SJRMOD is presently set for monthly time steps, although it can be modified for any desired time step, one day or greater. For comparison of Case Studies 1 and 2 a monthly interval is most convenient, although in future applications weekly intervals will be used to better represent fisheries release schedules.

Figure 4 shows the patterns of flow at Vernalis that would result according to the assumed schedule of salt load retention and release outlined above. According to this scenario the effects of drainage regulation on flows at Vernalis is once again comparatively minor, as a result of the large volumes of dilution water entering the system from eastside streams.

However, it is again of interest to note that again while flow reductions are small, Figure 5 shows the effects of salt load retention are increasingly significant as the stream flow diminishes over the three year period. In Case 2, the water quality degradation in the river at Vernalis is slightly higher during the periods of release since there is an attempt to put more salt out during a shorter period of time than in Case 1.

SUMMARY AND RECOMMENDATIONS

Goal of any salt load management program is to maintain the viability of agriculture on the Westside of the San Joaquin Valley and improve the quality of water in the San Joaquin River for the benefit of water users and fish and wildlife. Under proper management criteria this plan could eventually allow the completion of the San Luis Drain to Vernalis or Antioch. This would permit the utilization of the full dilution capacity of the entire flow of the San Joaquin Basin. It is conceivable that with careful control of irrigation water applications, some recycling of marginally saline drainage water and strict discharge limits, that additional land within the most severe drainage problem areas of the Federal San Luis Unit (Westlands Water District) could also be drained through the San Luis Drain without causing adverse water quality impacts.

It is recommended that in order to further evaluate the proposed management plan and as part of the five-year San Joaquin Valley Drainage Implementation Program, that:

1) Funding be provided by either any or all of the following agencies; the State Water Resources Control Board, the Environmental Protection Agency, the Bureau of Reclamation and/or the Department of Water Resources, to reconstruct some existing on-farm subsurface drainage systems on the Westside of the San Joaquin Valley. The systems that should be reconstructed are only those that cannot be shut off without the drainage effluent from those systems either ponding on the soil surface, causing extremely shallow water tables or flowing out of the system by gravity during the time the drains are shut off. These systems must also drain into open drains that convey drainage water to the San Joaquin River.

2) The reconstructed drainage systems only be allowed to operate when the flow in the San Joaquin River allows the safe discharge and transport of the saline water to the San Joaquin-Sacramento River Delta, the San Francisco Bay and the Pacific Ocean.

3) An extensive monitoring program be established for each of the reconstructed drains to analyze the impact of operating the system in conformance with this plan.

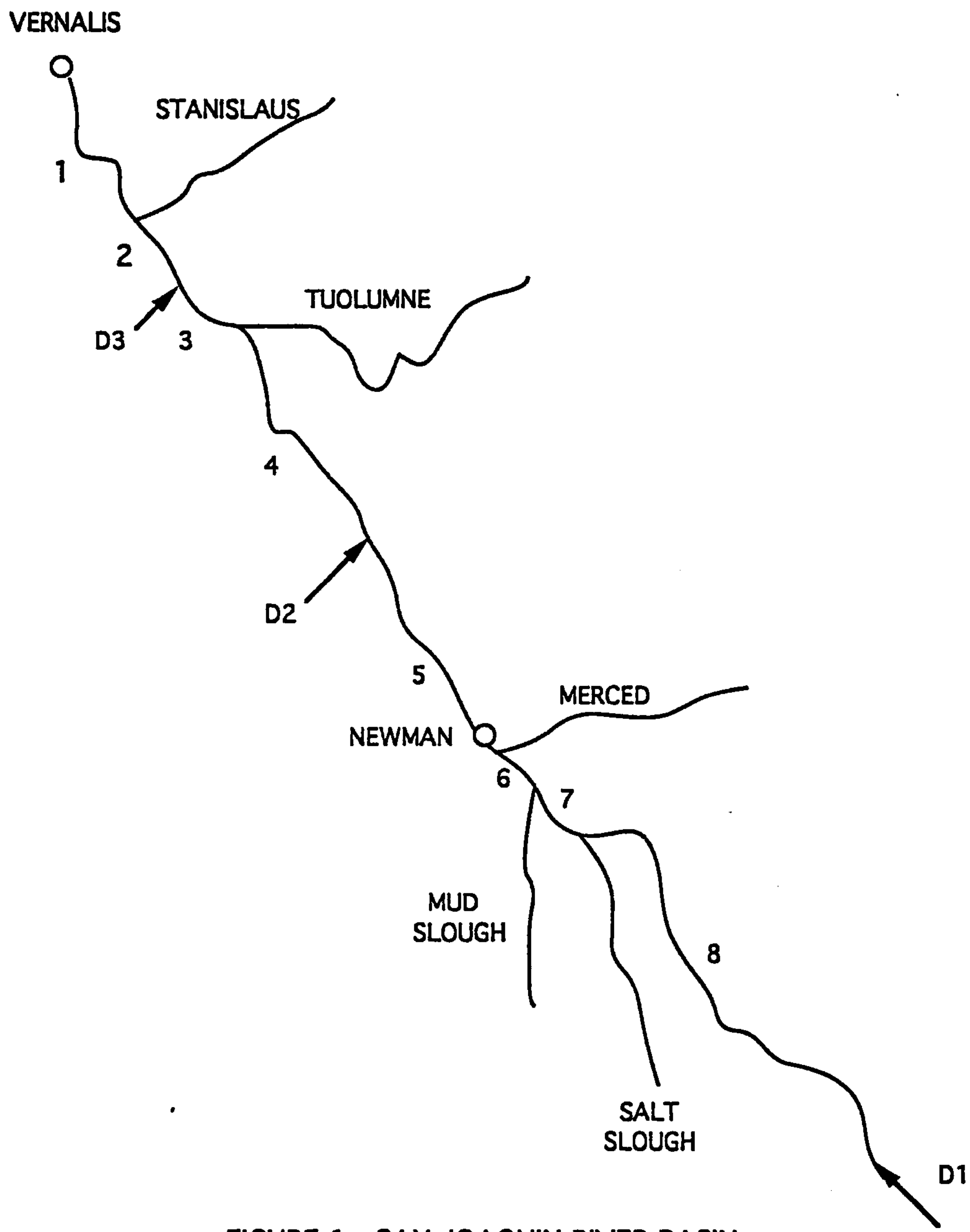

FIGURE 1 SAN JOAQUIN RIVER BASIN

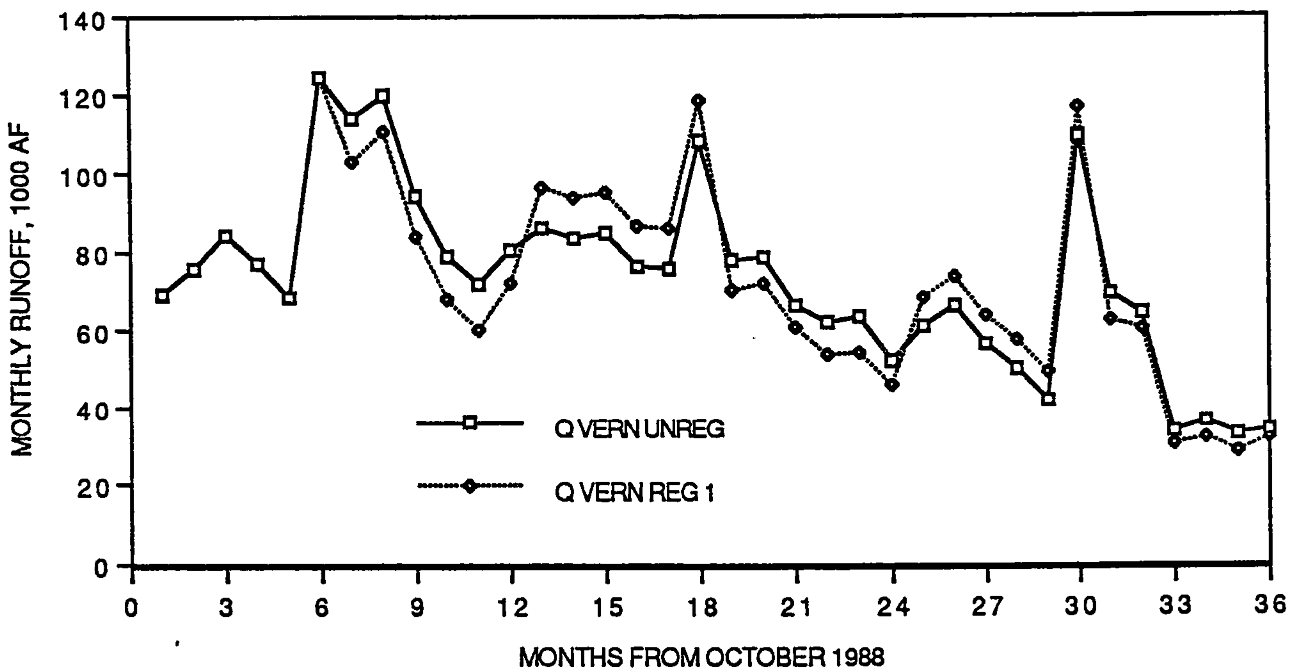

FIGURE 2 CASE 1, SEASONAL MANAGEMENT OF SALT LOAD

MONTHLY RUNOFF AT VERNALIS

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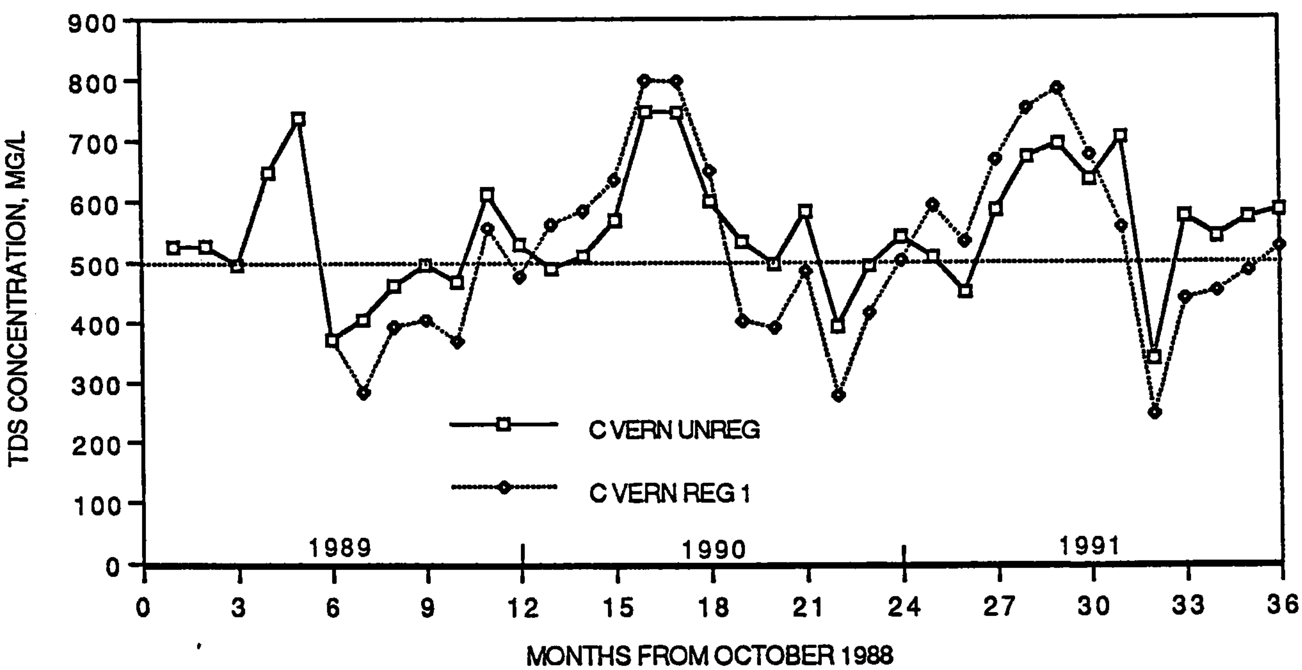

FIGURE 3

CASE 1, SEASONAL MANAGEMENT OF SALT LOAD
TDS CONCENTRATION AT VERNALIS

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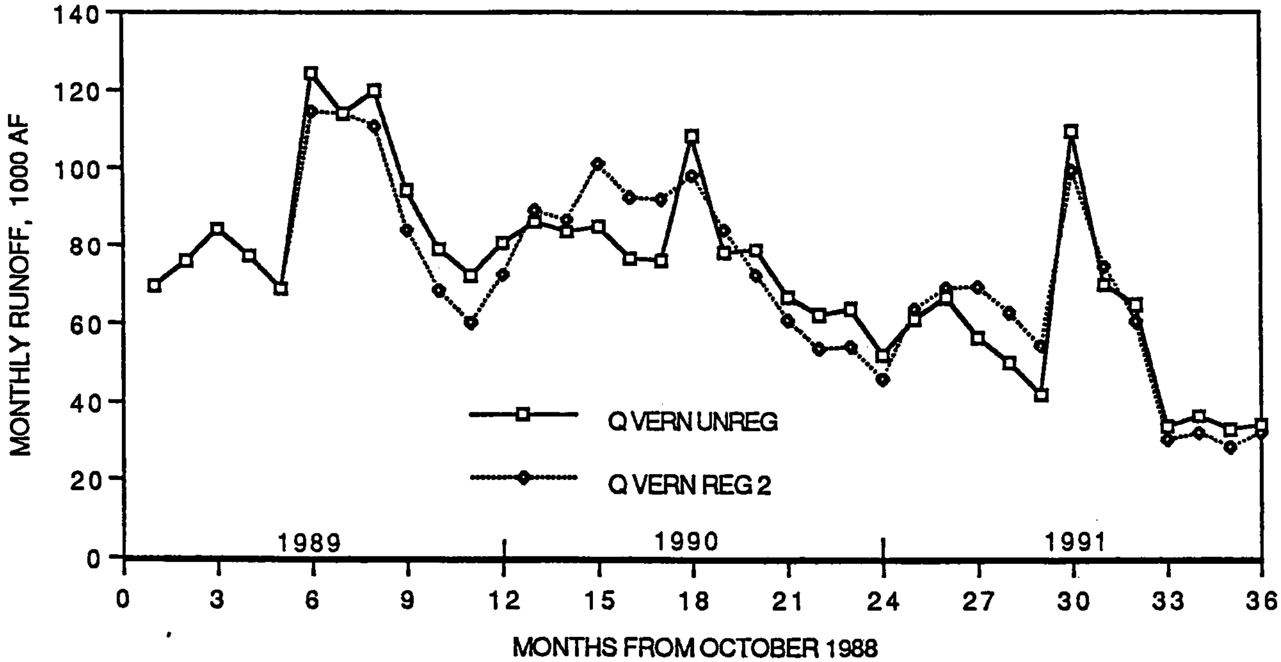

FIGURE 4 CASE 2, PLANNED MANAGEMENT OF SALT LOAD

MONTHLY RUNOFF AT VERNALIS

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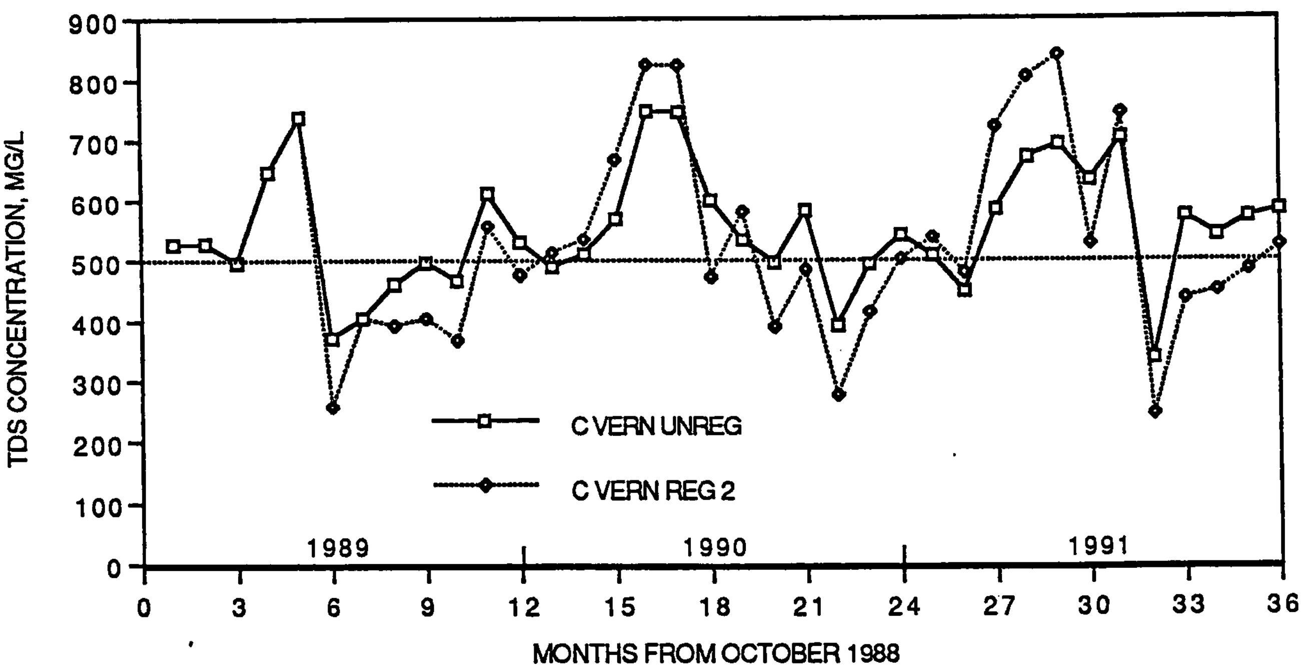

FIGURE 5

CASE 2, PLANNED MANAGEMENT OF SALT LOAD
TDS CONCENTRATION AT VERNALIS

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