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The Resources Agency

Department of Water Resources

BULLETIN No. 127

SAN JOAQUIN VALLEY DRAINAGE INVESTIGATION

Appendix D

WASTE WATER QUALITY, TREATMENT, AND DISPOSAL

APRIL 1969

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FOREWORD

This appendix summarizes the water quality phases of the San Joaquin Valley Drainage Investigation. The investigation started in 1957 and the preliminary edition of Bulletin No. 127 was published in January 1965. This report covers work done during that time span, though some 1965 pesticide data are included.

Direction of the water quality studies was modified in 1965. The Department emphasized collection of potential problem-causing constituent data--largely pesticides and nutrients. Collection of other waste water quality data continued, on a reduced scale, to permit evaluation of the accuracy of the earlier estimates. In early 1967 the redirected studies were merged with similar studies of the U. S. Bureau of Reclamation (USBR) and the Federal Water Pollution Control Administration (FWPCA). The studies are scheduled for completion in 1970, and will be reported upon either in the Department's Bulletin 174 series or in an interagency publication.

The material presented in the appendix was developed and is presented herein for a joint state-federal facility (the San Joaquin Master Drain). Because of repayment difficulties, the State withdrew from construction of a joint facility in early 1967. A Federal drainage facility (the San Luis Drain) is now under construction and will be completed in 1972. State drainage facilities will be constructed when required and when assurance of repayment is received. Though there may be separate federal and state facilities, the data herein presented are the best estimates of total agricultural waste water outflow from the San Joaquin Valley.

William R. Gianelli
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March 12, 1969

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ABSTRACT

This appendix reports the results of water quality studies that were part of the San Joaquin Valley Drainage Investigation. The area of investigation comprises the entire eight million acres of California's San Joaquin Valley. Drainage facilities are planned to accept subsurface agricultural waste waters that have been degraded to a point that they cannot be physically or economically reused for agricultural purposes. Municipal, industrial and oilfield waste waters may be accepted in the drainage facilities provided that they meet specified criteria. It is shown, however, that treatment and transportation to the drainage facilities of most municipal or industrial waste waters is not economically justifiable.

The present and future quality characteristics of the agricultural waste water of the San Joaquin Master Drain were determined through utilization and evaluation of two major studies: theoretical salt routing and monitoring of existing drain waters. These two studies enabled the Department to estimate the quality of water in the Master Drain from 1970 to the year 2020. Excluding nitrogen, it appears that there will be a negligible impact on the receiving water due to the discharge of the drainage facilities into the San Joaquin River near Antioch Bridge.

The Department retained a Biological Treatment Consulting Board to study and report on the feasibility of removing pesticides and algal growth potential from the San Joaquin Valley's drainage waters. Its primary recommendation was to construct a prepilot plant to determine the practicability of removing algal growth potential from the drainage waters and establish design criteria. The Department, the Federal Water Pollution Control Administration and the U. S. Bureau of Reclamation joined in a three-year study in 1967 to determine the economics of nitrogen removal treatment.

CHAPTER I
INTRODUCTION

The purpose of this appendix is to report the results of water quality studies that were part of the San Joaquin Valley Drainage Investigation. The purposes of the water quality studies were to:

1. Determine the present quality and predict the future quality of agricultural waste waters.

2. Evaluate the significance of the probable effects of the drain discharge on the receiving waters and investigate the need for treatment of the Master Drain effluent.

3. Appraise the possible benefits or consequences that would result both within the Master Drain and in the receiving waters by the acceptance or rejection of municipal, industrial, and oilfield waste waters.

Area of Investigation

The area of investigation included the entire San Joaquin Valley. This area, drainage problem areas, and the proposed alignment of the San Joaquin Master Drain are shown on Figure 1. Approximately 90 percent of the valley floor's eight million acres is considered to be irrigable. The Tulare Lake Basin portion of the valley floor contains 4.8 million acres and the San Joaquin River Basin portion contains 3.2 million acres. These two basins are separated by the natural topographic divide, also shown on Figure 1.

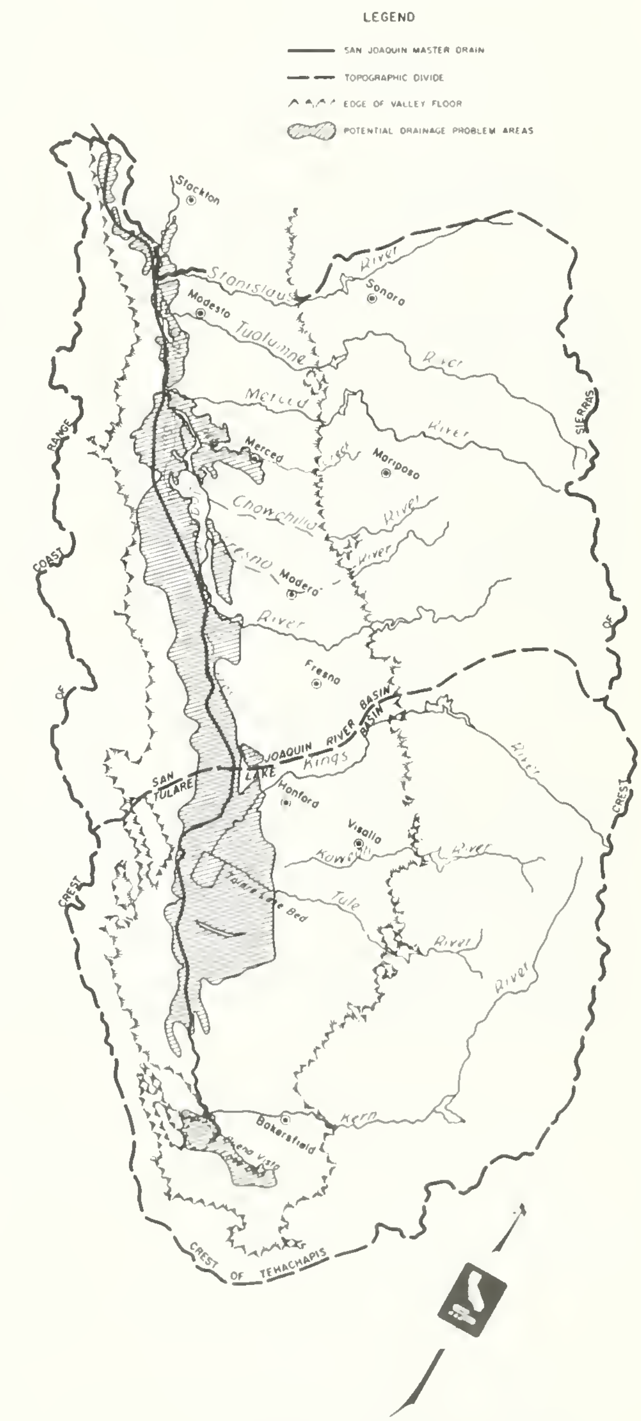


Figure I. AREA OF INVESTIGATION

CHAPTER II
AGRICULTURAL WASTE WATER

The purpose of the San Joaquin Master Drain is to provide a safe and orderly means of disposal for agricultural waste water of the San Joaquin Valley. The ultimate goal of this waste water disposal system is to develop a desirable inflow-outflow salt balance relationship that will protect the agricultural economy and reduce the degradation of surface and ground water in the Valley.

San Joaquin Valley Agricultural Waste Water Classification

Agricultural waste water is that water which can no longer be beneficially used in farming practices. It is drainage water that is not usable due to excessive concentrations of one or more constituents. If this water were used for irrigation, crop production would be reduced.

Since the major use of water in the San Joaquin Valley is for irrigation, it is considered advisable to classify these waste waters according to irrigation water quality criteria. The irrigation water quality criteria are generally based on total dissolved solids, electrical conductivity, chlorides, sodium percentage, and boron.

Irrigation Water Classification

Irrigation water was first classified in 1931 by the Extension Service of the University of California and the United States Department of Agriculture. Since then, different agencies, groups and individuals have revised and presented slightly different classifications, but in general the 1931 classification with minor alterations is still in use. Table 1 presents the suggested general limit for irrigation water in California, considering diverse climatological conditions and variation in crops and soils. The individual classes are explained as follows:

Class 1. Waters regarded suitable for irrigation of any crop and under any condition of climate and soil.

Class 2. Waters regarded as possibly harmful for irrigation use for certain conditions of climate and soil.

Class 3. Waters regarded as probably harmful for irrigation use even for the tolerant crops or with more favorable conditions of climate and soil.

These criteria have limitations in agricultural practice. In many instances a water may be wholly unsuitable for irrigation purposes under certain conditions of use, yet be completely satisfactory under other circumstances. Consideration must be given to the type of crop, soil permeability, drainage, temperature, humidity, rainfall, irrigation practices, and other conditions which can alter the response of a crop to a particular quality of water.

TABLE 1

QUALITATIVE CLASSIFICATION OF IRRIGATION WATERS

Chemical Properties	Class 1 Excellent to Good	Class 2 Good to Injurious	Class 3 Injurious to Unsatisfactory
Total Dissolved Solids, in mg/l[1/]	Less than 700	700-2000	More than 2000
Conductance in micromhos at 25° C.	Less than 1000	1000-3000	More than 3000
Chlorides in mg/l	Less than 175	175-350	More than 350
Sodium in percent of base constituents	Less than 60	60-75	More than 75
Boron in mg/l	Less than 0.5	0.5-2.0	More than 2.0

1/ mg/l = milligrams per liter

Major constituents that compose the total dissolved solids of agricultural waste water are calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, and nitrate. These major constituents, plus boron and silica, are discussed in Chapter V.

Nutrients, constituents of sanitary significance, and pesticides in agricultural waste water are discussed in the remainder of this chapter.

Agricultural Waste Water Quality

The quality characteristics of the agricultural waste water of the San Joaquin Master Drain were determined through the utilization and evaluation of two major studies undertaken during the course of the San Joaquin Valley Drainage Investigation.

One of the studies involved the use of a "salt routing technique" which estimated the quantity of water to be discharged into the San Joaquin Master Drain and its concentrations of total dissolved solids and sodium. These estimates considered both geographical and chronological changes. The other major study was a water quality surveillance program. The surveillance program results were used to determine and predict the constituents, other than total dissolved solids and sodium, that characterize the quality of San Joaquin Valley waters. The results and method of utilization of both of these studies are described in detail in Chapter V.

Nutrients

A nutrient is any substance that furnishes nourishment to promote growth. In agricultural practice, nutrient supplements are generally added by use of one or more of the numerous commercial fertilizers now on the market. The main element, however, in most fertilizers is nitrogen. Phosphorous compounds are also used in a high percentage of cases.

Agricultural drainage waters, both surface and subsurface, usually contain variable quantities of nitrogen and phosphorus. Sources of these elements, besides fertilizers, are irrigation waters, leaching of undeveloped land, nitrogen fixation and even a small amount from the atmosphere through precipitation.

Algal growth in drainage and receiving waters is promoted by nutrients. Although the kinds and amounts of nutrients required for the numerous forms of algae are not completely understood at the present time, it is known that both nitrogen and phosphorus are essential for life and may be limiting growth factors. Because of the uncertainty as to the amount and kind of nutrients required for algal growth, the general term algal growth potential (AGP) has been coined to encompass all the nutrients involved. The AGP of a material is a measure of its algal productivity or the quantity of algae that will grow in a given volume of the material. Even though this is a more general, and probably more applicable term, most of the work done to date has been to determine the concentrations of specific constituents present in the environment. Correlations of AGP to the chemical constituents have not yet been developed. The likelihood of uncommon algal growth is not merely determined for the sake of esthetics. A body of water choked with dead algae is definitely not a pleasing sight; moreover, the odor generated by the decaying organisms and the disagreeable taste imparted in the water are frequently significant. The dissolved oxygen depression caused by decaying algae may damage the fishery. Hydrogen sulfide produced by algal decomposition may damage painted surfaces. In addition, the possibility of materials being released that are hazardous to life itself must always be kept in mind.

The concentrations of the constituents of the nitrogen and phosphorus series in several types of water in the San Joaquin Valley are presented in Table 2. The "tile drains", referred to in Table 2, are the subsurface drainage systems located in the central part of the Valley in western Fresno and Merced Counties. A variety of crops are grown on the land serviced by these systems with different amounts of fertilizers being used.

An expanded program is presently being conducted to obtain more information on the form, concentration, and quantity of nitrogen and phosphorus in the locations where subsurface tile drains have been installed.

TABLE 2

AVERAGE CONCENTRATION OF NITROGEN AND PHOSPHORUS IN SEVERAL TYPES OF WATER IN THE SAN JOAQUIN VALLEY

Type	Nitrogen Series (in mg/l as N)				Phosphorus Series (in mg/l as PO_4)		
	Organic N	Ammonia NH_3	Nitrite NO_2	Nitrate NO_3	Ortho PO_4	Total PO_4 1/	Tot.+Org. PO_4 2/
Tile Drains	0.36	0.23	0.00	24.6	0.25	0.29	0.36
Tile Drains, Bennett Test Plot 4/	(1.17) 3/		--	5.34	--	--	0.74
Open Drains	0.50	0.25	0.03	1.40	0.42	0.51	0.85
San Joaquin River near Vernalis	0.46	0.14	0.01	0.48	0.33	0.40	0.52
Delta-Mendota Canal near Mendota	0.41	0.08	0.01	0.43	0.33	0.39	0.53

1/ Ortho plus polyphosphates.
2/ Total plus organic phosphates.
3/ (Organic + Ammonia) nitrogen.
4/ This field has not been cultivated.

Nitrogen compounds, other than the ammonium ion, are very soluble and not readily precipitated out or adsorbed as they seep through the soil and pass into the subsurface tile drains. Phosphorus compounds, however, are low in solubility and tend to form complexes with the soil.

The second line of Table 2 presents data for the Bennett Plot, a recently reclaimed parcel of land. As can be noted, the amount of nitrogen in its waste water is only about one-fifth the amount that occurs in areas with longer histories of fertilizer application.

The relatively low concentration of nutrients in the three surface waters listed can be attributed to factors such as dilution, utilization by aquatic organisms, flocculation, and sedimentation.

Nitrogen. Nitrogen is an essential element in the proteins of all living organisms and constitutes 78 percent of the atmosphere by volume. The nitrogen in nature goes through a cycle in which it is converted from one form to another. The more common nitrogen forms present in the cycle are organic nitrogen, ammonia, nitrite, nitrate, and elemental nitrogen. The exact nature of the nitrogen cycle varies with the ecology of the area.

Organic nitrogen includes all nitrogenous organic compounds such as amino acids and polypeptides in proteins. It is generally present in all surface waters as a result of the inflow of nitrogenous products from watersheds and the normal biological activity in water. However, it is usually present in very low concentrations in unpolluted waters. The average concentration of organic nitrogen in the valley floor's subsurface drains, surface drains, and irrigation waters ranged from 0.36 to 0.50 mg/l (milligrams per liter) as nitrogen (Table 2).

Ammonia compounds are used as fertilizers in agriculture. The ammonium ion is strongly adsorbed by the soil exchange complex and will not travel any appreciable distance until nitrifying bacteria change it to the nitrite or nitrate form. Ammonium is not usually found in aerated waters. Organic pollution is usually indicated when more than 0.1 mg/l ammonia nitrogen is present. Average concentrations of ammonia nitrogen ranging from 0.08 to 0.25 mg/l were found in various waters throughout the valley areas studied (Table 2).

Nitrite is not usually present in irrigation water since it is readily oxidized to the nitrate form under aerobic conditions. Like ammonia, its presence is an indication of organic pollution. The maximum average nitrite concentration occurred in open drain water, and this was only 0.03 ppm as nitrogen (Table 2).

Nitrate is generally the most prevalent form of nitrogen in water. Nitrates (expressed as nitrogen) in subsurface tile drainage system effluents comprised over 90 percent of the total nitrogen present. It is planned to accept only subsurface drainage water in the San Joaquin Master Drain; therefore, nearly all of the nitrogen contained in the water in the Drain should be in the nitrate form.

Phosphorus. The phosphorous compounds of significance in the chemistry of surface water are the phosphates or their molecularly dehydrated forms (polyphosphates). Phosphate compounds play a very important part in the metabolism of all living things. The energy of the phosphate groups directly or indirectly drive all the energy-requiring processes of life.

Phosphate compounds are present in nature in both organic and inorganic forms. Phosphate is a constituent of nearly all igneous rocks and occurs in small quantities in all soils. Vast deposits of calcium phosphate, with low solubility in neutral or slightly alkaline solutions, are found in the San Joaquin Valley floor. The principal source of phosphate fertilizers in this country is calcium phosphate. Phosphate fertilizers could yield some phosphates to the agricultural waste water but the majority are either utilized by plants or complexed with the soil.

Total phosphate is defined as inorganic orthophosphate and polyphosphate concentrations combined. Phosphate is also reported as total plus organic phosphate. Of the phosphate compounds found in water, the orthophosphates comprise approximately one-half of the total. Table 2 summarizes the concentrations of the various forms of phosphorus found in subsurface drains, surface drains, and surface water throughout the San Joaquin Valley. As can be noted in Table 2 the range of total plus organic phosphate concentrations is from 0.36 to 0.85 mg/l. This gives an indication of the low solubility of phosphates. The nature of phosphate compounds in irrigation cycles and drainage systems, however, is not completely understood due to the many parameters involved such as pH, temperature, soil and biological aspects.

Sanitary (Organic) Aspects

Water quality is also affected by the organic load of many other constituents. The major ones are discussed below.

Dissolved Oxygen. Inadequate dissolved oxygen in waters may contribute to an unfavorable environment for fish and other aquatic life and dissolved oxygen of one ppm or less may give rise to the odoriferous products of anaerobic decomposition. Presence of 5 mg/l of dissolved oxygen is usually regarded to be acceptable by most standards. The analyses of subsurface tile drainage effluents and open drain waters in the San Joaquin Valley floor indicate that dissolved oxygen concentrations of 6 to 8 mg/l were common throughout the year.

Biochemical and Chemical Oxygen Demands. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen utilized by microorganisms to stabilize the organic matter present. BOD is normally expressed in terms of the amount of oxygen required in five days and is thus called 5-day BOD. BOD in itself is not a pollutant and exercises no direct harm. However, the presence of excessive amounts of biodegradable organic matter, resulting in a high BOD, can cause an oxygen depression of such a degree as to be detrimental to the preferred forms of aquatic life.

Analyses of some of the existing agricultural waste waters in the San Joaquin Valley floor, including subsurface tile drainage effluents and open drain waters, show that the 5-day BOD of these waters is only about one percent of the BOD of domestic sewage. The range of 5-day BOD values found was from 1 to 3 mg/l.

Chemical oxygen demand (COD) is similar to BOD except that it depends on chemicals to degrade (oxidize) the organic material present. The COD technique converts organic matter to carbon dioxide and water regardless of the biodegradability of the substances. As a result, COD values are generally greater than BOD values. An advantage in using COD is that the analysis can be performed in a few hours as compared to the five days required for BOD. The average COD concentration in the subsurface tile drainage effluents was 20 mg/l and the open drain 30 mg/l. For comparison, oilfield waste water of the San Joaquin Valley commonly had COD concentrations of 400 mg/l.

Detergent (ABS), Phenolic Material, and Grease and Oil. Tests were conducted during the course of the investigation for detergents expressed as alkyl benzene sulfonates (ABS), phenolic material, and grease and oil. Traces of these materials were found in subsurface tile drains, open drains, the lower San Joaquin River, and the Delta-Mendota Canal near Mendota (Table 3).

TABLE 3

ORGANIC COMPOUNDS IN AGRICULTURAL WATERS
IN THE SAN JOAQUIN VALLEY
(Concentrations in milligrams per liter)

Type	Surfactant ABS	Phenolic Material	Grease and Oil
Tile Drains	Trace	0.001	0.8
Open Drains	Trace	0.001	0.8
San Joaquin River near Vernalis	Trace	0.000	1.2
Delta-Mendota Canal near Mendota	Trace	0.001	1.3

Although ABS was not expected to be found in subsurface drains, traces of it were detected. The source of ABS was not known, but it was probably derived from the applied surface water or used in pesticides as a wetting agent. The concentration of phenolic material was not significant, only 0.001 mg/l. Grease and oil appeared in most surface and subsurface tile drainage effluents at concentrations of about 0.8 mg/l.

Pesticides

The term "pesticides" refers broadly to substances or mixtures of substances intended to be used for controlling, preventing, destroying, repelling, or mitigating any pest. It includes insecticides, fungicides, rodenticides, herbicides, vermicides, defoliants, wood preservatives, etc.

The problem of identifying and determining the organic materials in water has received considerable attention in recent years mainly because of the greatly increased use of synthetic organic pesticides in agriculture. Pesticides in various forms are continually being developed and, consequently, their immediate and long-term effects on human beings and animals are largely unknown.

In 1961 there were over 9,000 commercial pesticide products. This figure represents a 15 percent increase over the previous year and twice the number listed in 1952. Of the over 200 different kinds of synthetic organic pesticides now in use, fewer than 30 account for 80 to 90 percent of the 900 million pounds sold annually.

Among the many variables and complexities which must be taken into account in evaluating pesticide measurements are the highly variable chemical composition of pesticides, collection of a truly representative sample, preparation of the sample, concentration of it for analysis, detection, and quantification of the results. The highly variable chemical composition of pesticides is due to the fact that they are frequently produced as by-products of other industrial activities.

Many pesticides are only slightly soluble in water and therefore tend to float on the water surface as a scum or oil slick. Some are heavier than water and have a tendency to settle to the bottom and intermingle with bottom sediments.

Present techniques can measure many pesticides in the parts per trillion (ppt) range (a ppt approximately equals a nanogram per liter), but it should be noted that one ppt is only 0.000,000,000,008 pounds per gallon (the usual sample size).

The problem of reporting pesticide concentrations is very perplexing. Many reports give the results of pesticide determinations as "computed maximum total chlorinated hydrocarbons" (CMT). This concentration is defined as the quantity of a nonspecific group of compounds with a molecular structure containing 50 percent chlorine. Chlorinated hydrocarbon insecticides are the most important single group of pesticides. Relating chlorinated hydrocarbon insecticides to computed maximum total chlorinated hydrocarbons is grossly misleading. There are at least two reasons for this: the chlorine content of insecticides range from 31 percent to 73 percent, and nonpesticide chlorinated hydrocarbons are often present. In order to overcome these shortcomings the current practice is to present pesticide information as the summation of identified chlorinated hydrocarbon pesticides.

Methods of Collection and Analyses of Samples. The carbon adsorption technique, developed by the U. S. Public Health Service, was utilized for pesticide detection at the beginning of this investigation. The sample was collected by passing a known volume of water through a column of activated carbon. The quantity of water that was passed through individual carbon filters varied between 1,000 and 10,000 gallons. An orifice maintained the flow through the carbon at a rate slightly below 10 gallons per minute per square foot of filter cross-section area. Where turbidity was a problem, sand pre-filters were installed. Settling tanks were also occasionally used prior to the sand filters as a further aid in removing turbidity. Upon completion of the collection period, which usually lasted a week, the carbon cylinders were delivered to the laboratory for analysis. The analytical procedure followed for the carbon adsorption technique is very expensive and tedious. Seven extractions are required to prepare the sample for the determination of the chlorinated hydrocarbon content (to extract the aromatic compounds).

The carbon adsorption analysis technique was replaced in the fall of 1963 by the microcoulometric gas chromatographic method. These analyses were performed by a private laboratory until approximately mid 1966 when the Department developed the capability to do this work. Gas chromatographic techniques are able to measure pesticides in the parts per trillion range. They have long been recognized as the most sensitive instrumental techniques for determining trace amounts of organic compounds; however, only recently have they been refined for pesticide determinations.

Gas chromatography is divided into three basic functions. First, a small quantity of concentrated sample is injected into the unit through a hypodermic needle, vaporized, and mixed with a carrier gas. Second, the carrier gas transfers the vaporized sample through a heated chromatographic column which is packed with porous material coated with high temperature boiling liquids. As the sample passes through the column the individual organic compounds in it travel at different rates and therefore emerge at the end of the column at different times. Third, a detector at the end of the column converts the individual organic compounds into an electrical response which is then transmitted to a recorder. The recorder plots peak heights versus retention time, from which the quantity as well as the identification of specific pesticides can be determined.

Results and Discussion. Typical water samples from the San Joaquin River, subsurface tile drainage effluents from western Fresno County, and open drains carrying mainly agricultural waste water were analyzed for aromatic content by utilizing the carbon adsorption technique. Table 4 presents the summary of the aromatic concentration detected in waters of the San Joaquin Valley.

As can be observed in Table 4, the average concentration of aromatics in open drain water is much higher than the average concentration in subsurface drainage water. This difference is probably due to the affinity that this class of organic chemicals has for suspended solids.

TABLE 4

SUMMARY OF AROMATIC CONCENTRATION DETERMINED BY UTILIZING THE CARBON ADSORPTION TECHNIQUE IN THE SAN JOAQUIN VALLEY
(Concentrations in parts per billion)

Location	Maximum	Average	Minimum
San Joaquin River			
Near Vernalis (11/61-3/63)	2.00	1.14	0.67
At Fremont Ford Bridge (9/61-5/63)	1.10	0.84	0.48
Above Kerckhoff Reservoir (4/62-1/63)	0.49	0.44	0.40
Subsurface tile drainage effluents (5/62-5/63)	2.05	0.71	0.23
Open drains (10/61-10/62)	12.06	5.73	2.50

<u>Chlorinated Hydrocarbon Pesticides</u>. Table 5 is a summary of the chlorinated hydrocarbon pesticides identified in samples analyzed by the microcoulometric gas chromatographic method. These samples were collected from Central Valley's surface waters, San Joaquin Valley subsurface tile drains and open drains, and ocean and San Francisco Bay waters between September 1963 and December 1965. Included in the summary are the individual pesticides detected, the number of times detected, the average summation of the detected chlorinated hydrocarbon pesticides, summation of the total times detected, and the total number of analyses. In the Central Valley's surface waters, for example, chlorinated hydrocarbon pesticides were found in 343 out of 390 analyses. Out of the 343 analyses the individual detected chlorinated hydrocarbons were found only the number of times listed in the times-detected column of Table 5.

The average pesticide concentrations detected in the supply water, subsurface tile drains, and ocean and bay waters are approximately the same, but the pesticide concentrations in open drains are significantly larger. It is interesting to note that although the carbon adsorption technique and the microcoulometric gas chromatographic method incorporated different principles and means of indicating pesticides (Tables 4 and 5), the ratios of the concentrations detected in open drains to the concentrations detected at other locations were approximately the same for both methods.

TABLE 5

CHLORINATED HYDROCARBON PESTICIDE SUMMARY
AVERAGE OF DETECTED CONCENTRATIONS

September 1963 through December 1965
(Concentrations in parts per trillion)

Pesticide	San Joaquin Valley Tile Drains 1/		Central Valley Surface Drains		Central Valley Surface Waters		Bay & Ocean Waters	
	Times Detected	Avg. Conc.	Times Detected	Avg. Conc.	Times Detected	Avg. Conc.	Times Detected	Avg. Conc.
Aldrin	0	--	2	50	3	13	2	10
BHC	2	900	10	31	33	38	9	36
Chlordane	0	--	10	108	16	125	0	--
CIPC	0	--	1	120	4	47	0	--
DDE	16	25	53	57	114	24	23	26
DDD &/or DDT	62	78	168	320	301	76	70	50
Dieldrin	13	35	11	64	37	26	6	27
Endrin	0	--	2	595	1	10	0	--
Heptachlor	0	--	2	15	13	20	4	18
Heptachlor Epoxide	25	14	47	22	129	19	27	21
Kelthane	0	--	0	--	3	25	1	60
Lindane	22	35	43	25	86	21	24	18
Methoxychlor	0	--	1	450	0	--	0	--
TCBC	1	50	0	--	1	65	0	--
Tedion	0	--	2	325	0	--	1	50
Thiodan	0	--	2	275	0	--	0	--
Toxaphene	13	528	107	1,680	85	166	8	174
Summation	63	247	182	1,340	343	143	76	95
No. of Analyses	66		188		390		81	

1/ Bennett Test Plot data excluded.

The most prevalent pesticides found were DDT and/or DDD (the analyses did not distinguish between DDT and DDD), DDE, and toxaphene. It should be noted that DDT can degrade to DDD and DDE.

The opinion has been expressed in several technical papers that pesticides below one part per billion should have no appreciable toxic effect on food chains and aquatic life cycles. Very few stations were found in the San Joaquin Valley where the summation of identified chlorinated hydrocarbon pesticides, as determined by gas chromatography, were in excess of one-half part per billion; therefore, pesticides are not expected to create any problems in the drainage system or receiving waters as a result of the operation of the Master Drain.

CHAPTER III
NONAGRICULTURAL WASTE WATERS

Municipal and industrial waste waters, including oilfield waste waters, are generally conducted to a local waste disposal facility, and receive varying degrees of treatment after which they are returned to the environment by one or more of several different methods. These waste waters, if not adequately treated and properly disposed of, may create pollution problems in ground and surface waters.

Because of the nature and geographical location of municipal and associated industrial waste waters within the Valley in comparison with the oilfield waste waters found there, it is more convenient to discuss the two classes of waste water separately.

Municipal and Industrial Waste Water

Studies were made of municipal and industrial waste water to determine the quantity distribution, quality variation, and disposal methods presently practiced in the San Joaquin Valley.

The California Central Valley Regional Water Quality Control Board surveys, establishes, and monitors quality requirements for all the major waste discharges in the Valley. The Department periodically monitors and samples waste water effluent in conjunction with those activities of the Board.

References utilized in these studies were "Reclamation of Waters from Sewage and Industrial Wastes in California, July 1, 1955-June 30, 1962", Bulletin No. 68-62, Department of Water Resources; "Water Use by Manufacturing Industries in California, April 1964", Bulletin No. 124, Department of Water Resources; and "Inventory of Municipal Waste Facilities in California, 1960", United States Public Health Service.

The surveys and references above were used to develop a comprehensive waste water quality and quantity analysis for the municipal and industrial waste waters of the Valley so that a reasonable estimate could be made of the amount of additional treatment that may be necessary before these waste water effluents could be accepted into the Master Drain.

Present Conditions of Facilities

The total number of municipal and industrial waste water facilities and the degrees of treatment prior to disposal are shown in Table 6. Of the 112 waste water disposal facilities surveyed, 39 had primary treatment and 73 had secondary treatment. Primary treatment accounted for 22 percent of the total flow--

29 million gallons per day (mgd) or 32,000 acre-feet per year (ac-ft/yr). Secondary treatment accounted for 78 percent--104 mgd or 116,000 ac-ft/yr. Table 7 presents the total quantity of waste water for each county surveyed in the San Joaquin Valley. The data presented in Tables 6 and 7 is representative of average conditions during the 1960 to 1964 period.

TABLE 6
TYPE OF TREATMENT OF MUNICIPAL AND INDUSTRIAL WASTE WATER IN THE SAN JOAQUIN VALLEY

Type of Treatment	Number of Waste Disposal Facilities	Quantity of Treated Waste (million gallons per day)	Quantity of Treated Waste: Percentage
Primary	39	28.9	22
Secondary	73	103.8	78
Total	112	132.7	100

TABLE 7

METHODS OF DISPOSAL OF MUNICIPAL AND INDUSTRIAL WASTE WATER BY COUNTIES IN THE SAN JOAQUIN VALLEY

County	Quantity of Treated Waste (million gallons per day)			Percentage of Valley Total		
	Disposal to Land	Disposal to Waterways	Total Disposed	To Land	To Waterways	By County
Fresno	32.6	1.3	33.9	24.5	1.0	25.5
Kern	23.2	0	23.2	17.5	0	17.5
Kings	1.5	2.5	4.0	1.1	1.9	3.0
Madera	3.1	0	3.1	2.3	0	2.3
Merced	6.2	5.3	11.5	4.8	3.9	8.7
San Joaquin	7.4	18.8	26.2	5.6	14.2	19.8
Stanislaus	5.9	13.1	19.0	4.4	9.9	14.3
Tulare	11.2	0.6	11.8	8.5	0.4	8.9
Total	91.1	41.6	132.7	68.7	31.3	100.0

It should be noted that the definitions of primary and secondary treatment are quite arbitrary. Therefore, some of the classifications in this investigation may not be identical to the classification given for the same waste water disposal treatment facility in other reports and by other agencies.

The San Joaquin Valley has few perennial rivers that contain enough flow during the summer months to assimilate the entire quantity of treatment plant effluent; consequently, approximately 69 percent (91 mgd or 102,000 ac-ft/yr) of the total waste water effluent is applied to the land surfaces for disposal by evaporation, percolation, or utilization as irrigation water (Table 7).

The results of ground, surface, and waste water quality surveys indicate the degree of treatment and disposal afforded to municipal and industrial waste waters in the San Joaquin Valley is generally adequate and the removal of these final effluents by the Master Drain is not required at the present time.

The majority of the urban areas and their effluents are on the east side of the Valley whereas the main agricultural drainage problem areas and the planned alignment of the San Joaquin Master Drain are on the west side of the Valley (Figure 1).

Future Waste Water Disposal Considerations

The major factors that may affect the future quantity and quality of municipal and industrial waste water include population growth, per capita water consumption changes, and industrial expansion. However, the quality of the waste water is expected to stay approximately constant and the quantity increase is assumed to be a direct function of population growth.

The predicted increase in total population, urban population, and urban water requirements per ten-year interval (1970 to 2020), was calculated by the Department of Water Resources. Analyses of data from the San Joaquin Valley have indicated that the quantity of urban waste water is approximately 50 percent of the quantity of urban water used. This figure was used to calculate the future quantities of urban waste water for the eight San Joaquin Valley counties, as shown in Table 8.

Table 9 presents a summary of the effluent quality of the major municipal waste water treatment plants in the Valley.

TABLE 8

PROJECTED URBAN WASTE WATER QUANTITIES
FOR SAN JOAQUIN VALLEY
(Quantities in 1,000 Ac-ft/yr.)

County	1970	1980	1990	2000	2010	2020
Fresno	66.4	107	152	207	280	364
Kern	39.1	53.3	77.6	110	150	190
Kings	4.3	7.7	13.8	20.4	29.1	41.3
Madera	4.8	6.6	10.6	16.1	25.1	37.5
Merced	10.0	13.7	20.7	28.7	40.2	58.5
San Joaquin	31.3	46.2	77.4	138	209	298
Stanislaus	21.2	28.0	38.3	54.0	82.5	105
Tulare	15.2	20.8	29.0	38.5	50.0	64.0
Total	192.3	283.3	419.0	612.7	865.9	1,158.3

Alternative Waste Water Disposal Systems

The two logical choices for future and existing municipal and industrial waste water disposal facilities are (1) local treatment and disposal or reuse and (2) local treatment and transfer to the San Joaquin Master Drain.

Table 10 presents estimated costs for secondary treatment and conveyance to the Master Drain for the urban waste waters from several areas of the San Joaquin Valley. These costs are based on the projected 1990 quantities. The column "Conveyance to the Master Drain" includes only the cost of buried pipelines and terminal pumping plants between the disposal facility and the Master Drain. It does not include the additional cost of treatment involved before the waste water effluent would meet the "criteria" presented in Chapter VI. A minimum of secondary treatment would be necessary to meet these "criteria". The column "Secondary Treatment" is the estimated cost of constructing new, or reconstructing and expanding existing, primary and secondary waste water disposal facilities to handle the predicted 1990 waste water quantities.

TABLE 9

WASTE WATER TREATMENT PLANT EFFLUENT QUALITY ANALYSES IN THE SAN JOAQUIN VALLEY[1/]

	Maximum	Average	Median	Minimum
Specific Conductance (micromhos at 25° C.)	10,000	1,109	692	317
pH	11.1	7.3	7.2	4.2
Mineral Constituents (in milligrams per liter)				
Calcium	103	30.2	25	7.2
Magnesium	77	14.1	14	0.0
Sodium	2,160	157	77	32
Potassium	95	14.2	12	3
Ammonium	43	15.1	14	0.3
Carbonate	72	0.8	0	0
Bicarbonate	771	275	262	0
Sulfate	234	35	23	0.0
Chloride	2,700	160.2	54	0.6
Nitrate	92	6.6	0.8	0.0
Phosphate	58	21.5	20	2.0
Fluoride	4.0	0.9	0.5	0.0
Boron	20	0.6	0.4	0.0
Silica	98	46	42	15
Total Dissolved Solids	4,640	550	422	179
Percent Sodium	90	53	50	28
Hardness as $CaCO_3$ (in milligrams per liter)				
Total	503	130	127	20
Noncarbonate	154	5	0	0

1/ From Table C-5, Department of Water Resources Bulletin No. 68-62, "Reclamation of Water from Sewage and Industrial Wastes in California, July 1, 1955-June 30, 1962".

TABLE 10

ESTIMATED COMPARATIVE COST FOR DISPOSAL OF URBAN WASTE WATER
(Capital improvements only, based on 1965 construction costs)

City	1990 Design Flow in Million Gallons per Day	Costs of Conveyance to the Master Drain[1/] in Dollars	Costs of Secondary Treatment in Dollars
Bakersfield Area	79.2	8,970,000	9,790,000
Oildale	7.6	1,720,000	1,530,000
Fresno Area	159	20,662,000	13,800,000
Clovis	2.0	1,601,000	504,000
Sanger	3.9	2,770,000	982,000
Fowler	0.7	531,000	229,000
Malaga	0.5	108,000	173,000
Merced Area	14.4	7,311,000	2,550,000
Atwater	5.4	2,440,000	1,150,000
Gustine Area	1.9	63,000	520,000

1/ These costs are valid only if all listed cities participate, excluding the Gustine Area.

At the present time and in the foreseeable future the methods employed to dispose of the waste water effluent from both the primary and secondary municipal treatment plants appear generally adequate.

Each urban area that is close to the Master Drain will have to evaluate its own position as to the economics of either transporting the waste water effluents to the Master Drain or to local disposal systems for reuse or disposal. However, this accounts for only a small quantity of the Valley's total waste water.

A municipal and industrial waste water canal or pipeline parallel to the length of the Valley on the east side has been considered as a possibility in the event that a significant impairment of the ground or surface water results from the waste water disposal practices. However, before such a canal or pipeline would be built, a detailed regional study would be necessary to ascertain the feasibility of the plan. This study would necessarily consider the value of treated waste water for ground water recharge and the cost of transportation.

The disposal of most of the Valley's municipal and industrial waste water cannot be economically justified now or in the foreseeable future because of the costs of conveyance and the required treatment. Therefore, municipal and industrial wastes are not included in the predicted quantities of waste water in the Master Drain.

Oilfield Waste Water

The majority of California's oilfields are in the southern half of the San Joaquin Valley. The Valley as a whole produces two-fifths of the State's petroleum with the resultant discharge of large quantities of oilfield waste water.

The publication entitled "1962 Executive Officer's Progress Report to the Central Valley Regional Board", published by the Central Valley Regional Water Pollution Control Board[1/], contains results of a complete oilfield waste water inspection survey in the Valley. The Board establishes the requirements governing the quality of the oilfield waste water effluent discharged and has scheduled a complete general monitoring of oilfield waste water at least every three years, and at least once every year in problem or potential problem areas. The Department of Water Resources also samples the oilfield waste waters as conditions warrant.

In 1962 approximately 67,000 acre-feet of oilfield waste water were disposed of in the Valley. The oilfield waste water disposal practices in the Valley were found to be in general compliance with the requirements established by the Board. The importance placed on oilfield waste water disposal is reflected by the fact that in 1962 an estimated one million dollars was expended by oil producers for waste disposal facilities in the Valley.

Oilfield waste water disposal methods throughout the San Joaquin Valley include: (a) injection into abandoned oil wells; (b) disposal into ponds for evaporation and percolation; and (c) use as an irrigation supply. The Central Valley Regional Water Pollution Control Board's 1962 Executive Officer's Progress Report indicated that less than one percent of the oilfield waste water was disposed of in such a manner as to constitute a possible threat of pollution.

1/ Now named the Central Valley Regional Water Quality Control Board.

Quality, Quantity, and Disposal

Oilfield waste water in the San Joaquin Valley varies in chemical composition from oil well to oil well, but in general oilfield waste water from the western portion of the Valley has a considerably higher mineral concentration than that from the eastern portion. The waste from the west is of such quality that it cannot be used for irrigation, whereas the major part of the 33,600 acre-feet produced in the eastern portion can be used for that purpose. The difference in quality between the wastes of the two can be inferred from the disposal methods used (Table 11).

TABLE 11

DISPOSAL OF OILFIELD WASTE WATERS IN THE SAN JOAQUIN VALLEY1/

Method of Disposal	East Side		Valley Floor		West Side		Total Acre-feet per year	Percent of total
	Acre-feet per year	Percent per year	Acre-feet per year	Percent per year	Acre-feet per year	Percent per year		
Irrigation	33,600	50	0	0	0	0	33,600	50
Injection2/	1,400	2	6,400	13	2,300	3	12,100	18
Evaporation	0	0	140	0.2	0	0	140	0.2
Percolation	0	0	0	0	20,700	31	20,700	31
Non-approved Sites3/	0	0	460	0.8	0	0	460	0.8
Total	35,000	52	9,000	14.0	23,000	34	67,000	100.0

1/ 1962 data.
2/ Through wells penetrating deep-lying aquifers not pumped for water supply.
3/ Producers have not met Water Quality Control Board Standards which are in effect to prevent pollution of usable water resources.

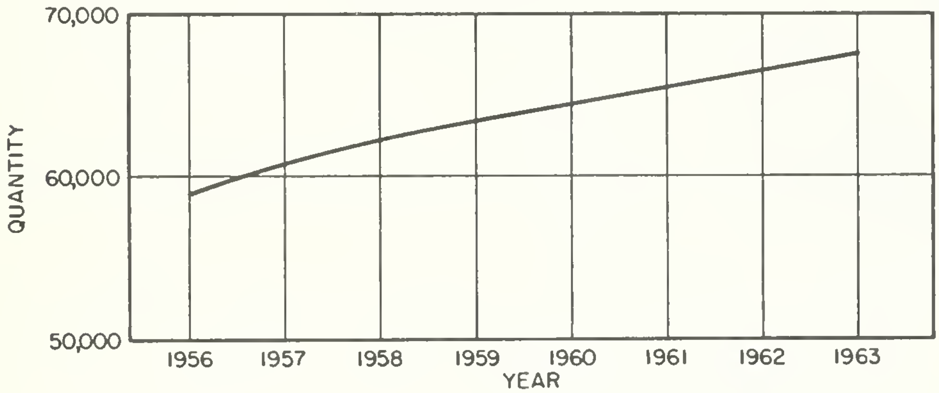
Of the 67,000 acre-feet of oilfield waste water produced in 1962, approximately 50 percent (33,600 acre-feet) was used for irrigation; 18 percent (12,100 acre-feet) was pumped into deep aquifers that contain water not considered to be of beneficial use; 0.2 percent (140 acre-feet) was disposed of by evaporation; 31 percent (20,700 acre-feet) was disposed of by percolation; and only 0.8 percent (460 acre-feet) was disposed of at nonapproved sites which could constitute a possible threat of pollution.

Figure 2 is a plot of the quantity of oilfield waste water produced from 1956 to 1963. A straight line projection indicates an increase in the quantity of about 1,300 acre-feet per year or approximately 2 percent per year.

Oilfield waste waters were not found to be posing a significant threat of pollution to the usable water resources of the San Joaquin Valley at the present time. Therefore, considering the treatment necessary for acceptance, the expense of conveyance, the numerous disposal methods already in use, and the large investments made for the present disposal systems by the oil producers, it was concluded that the conveyance of oilfield waste water to the San Joaquin Master Drain would not be justified. Hence, oilfield waste waters are not included in the quantities predicted in the Master Drain.

Figure 2. QUANTITY OF OILFIELD WASTE WATER PRODUCED IN THE SAN JOAQUIN VALLEY

(ACRE-FEET PER YEAR)



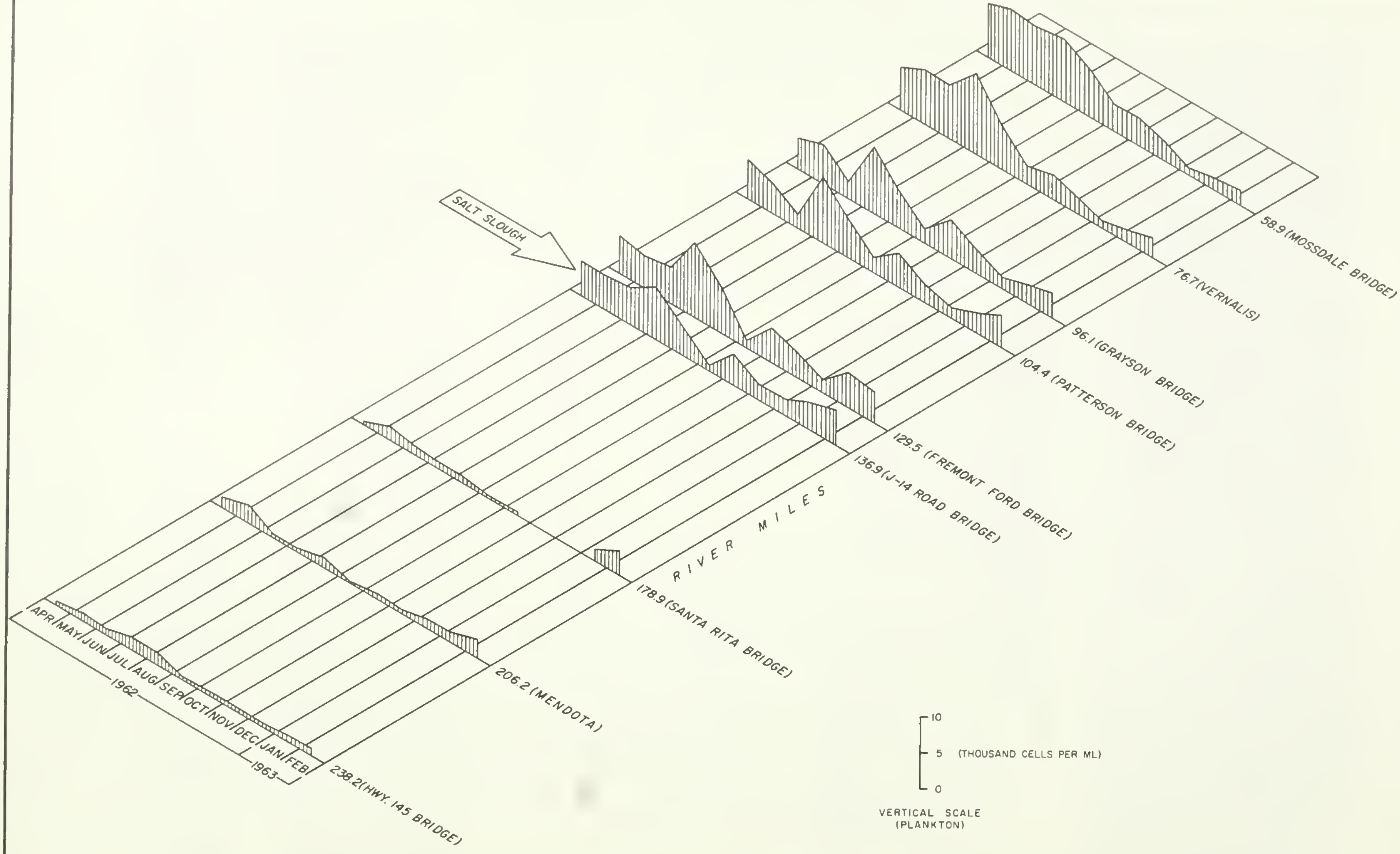


Figure 3. SAN JOAQUIN RIVER, AVERAGE TOTAL PLANKTERS PER MILLILITER
BY MONTH AND STATION

CHAPTER IV
PLANKTON OF THE SAN JOAQUIN VALLEY

In order to determine the types of algae present in the waters of the San Joaquin Valley and the quantities of these organisms, and to predict the conditions under which toxic or nuisance blooms might occur, William C. Vinyard, Ph. D. of Humboldt State College conducted a series of biological studies for the Department. These studies were made from January, 1962 to June, 1963 and considered free-floating plant life in the size range of 50 to 500 microns (1,000 microns equal 1.0 millimeter).

Plankton samples were taken weekly at 11 stations. Miscellaneous plankton samples were also collected at other locations on the San Joaquin River and its tributaries, open waste water drains, and subsurface tile drains. Algal counts by genera and counts of the total number of organisms per milliliter were determined from the plankton samples. Other concentrations or values also determined weekly were flows, temperature, dissolved oxygen, specific conductance, pH, hardness, selected minerals, biochemical oxygen demand (BOD), chemical oxygen demand (COD), surfactant (ABS), phenolic material, and grease and oil.

The definition of an algal bloom is very arbitrary. Some investigators have expressed the opinion that 500 organisms per milliliter should be considered a bloom. However, this definition does not consider the variance in the size or significance of the genera present. Other investigators believe that a bloom should be expressed in terms of a centrifuged volume and would thus be expressed in quantity per unit volume, (mg/l or ppm, ml/l, etc.). Using the centrifuged volume as a basis for definition, a bloom is often considered to be present when a sample contains a centrifuged volume of organisms in the range of 40 to 50 mg/l.

Figure 3 presents results of the total counts made on the nine San Joaquin River stations which were sampled weekly as part of Dr. Vinyard's studies. Two additional stations were sampled: the Delta-Mendota Canal and Salt Slough. The latter flows into the San Joaquin River between the stations at miles 129.5 and 136.9. From Figure 3 it can be seen that plankton concentrations increase downstream from mile 178.9. During low flow months, the highest levels of mineral content in the river occur just upstream from the mouth of the Merced River (mile 123.75) due to the inflow of agricultural drainage water. The levels of mineral content generally diminish below each of the three major eastside tributaries--the Merced, Tuolumne (mile 91.0), and Stanislaus (mile 79.7) Rivers.

The miscellaneous samples, referred to previously, were examined to determine the relative abundance of algal genera present. Several genera of algae were found in the surface and waste waters. However, no algae were found in the subsurface tile drainage effluents.

The growth and reproduction of algae is dependent on nutrients, light, temperature, etc. From a knowledge of the climate in the study areas, and by reference to plankton count summaries, it was found that the algal populations were comprised chiefly of diatoms during the cooler, short days of spring and autumn. During the warm, long days of summer the diatoms were minimal in number and blue-green algae were predominant.

Only two toxic algal genera were identified in the study but neither was in sufficient numbers or remained long enough to be considered significant.

Dr. Vinyard predicted that during spring and summer months (April to September), when nitrogen and phosphorus concentrations and temperature are relatively high algal growths in surface drainage facilities can be expected to cause nuisance conditions. With proper operation and maintenance, excessive growths of algae will be controlled and will not be significant in the San Joaquin Master Drain's facilities.

CHAPTER V
PREDICTIONS OF THE SAN JOAQUIN MASTER DRAIN WATER QUALITY

The methods used to estimate the concentrations of the constituents in the waste water of the Master Drain are described in this chapter.

Salt Routing Technique

The quantity of water and representative concentration of total dissolved solids (commonly referred to as salts) and sodium in the water that will be collected in subsurface drains and then discharged into the San Joaquin Master Drain were estimated by a salt routing technique. The studies for the salt routing techniques were all made on lands where agricultural drainage problems exist today or may exist in the future. Eight study zones were delineated within the Valley as illustrated in Figure 4. Table 12 presents the estimated quantities and quality of the drainage water from the separate zones for the first thirty years of operation (1970-2000). The composite Master Drain quantity-quality picture is presented in Figure 5. These estimates are for the character of the material in the Drain for the period from 1970 to 2050.

TABLE 12

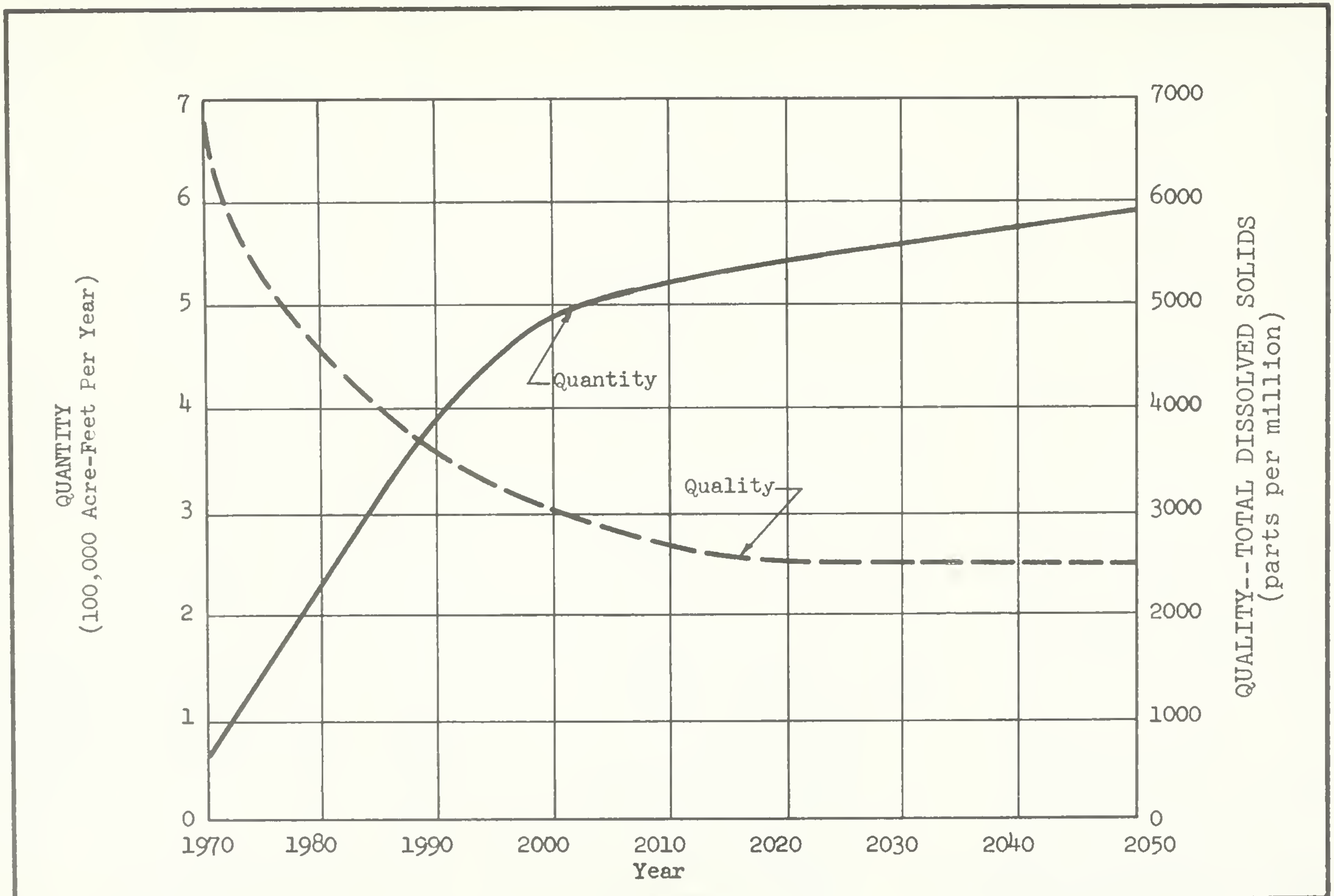
ESTIMATED QUANTITY AND QUALITY OF AGRICULTURAL WASTE WATER DISCHARGED INTO THE SAN JOAQUIN MASTER DRAIN BY THE SALT ROUTING TECHNIQUE

	1970			1980			1990			2000		
Zone	Quantity A-F[1/]	TDS[2/] (mg/l)[3/]	Sodium (mg/l)	Quantity A-F	TDS (mg/l)	Sodium (mg/l)	Quantity A-F	TDS (mg/l)	Sodium (mg/l)	Quantity A-F	TDS (mg/l)	Sodium (mg/l)
I	4,300	1,100	230	11,[illegible]00	1,000	180	19,300	1,000	190	24,000	1,[illegible]	180
II	3,300	2,000	490	7,500	1,200	[illegible]	17,[illegible]00	2,000	520	28,000	1,[illegible]	[illegible]
III	3,700	2,500	620	11,[illegible]00	1,200	230	17,[illegible]00	1,000	210	17,[illegible]	[illegible]	160
IV	15,600	5,500	1,400	48,300	1,[illegible]00	410	73,200	1,900	410	72,[illegible]	1,3[illegible]	[illegible]
V[4/]	6,600	16,400	4,800	[illegible]	8,1[illegible]	1,[illegible]00	137,400	4,600	1,[illegible]	[illegible]74,400	3,[illegible]	660
VI	29,300	7,300	2,100	70,[illegible]00	4,800	1,400	[illegible]7,300	3,[illegible]00	860	[illegible]	3,8[illegible]	[illegible]
VII	0	0	0	1,000	12,[illegible]	4,100	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
VIII	0	0	[illegible]	[illegible],200	7,600	2,300	14,[illegible]00	[illegible],100	1,[illegible]00	[illegible]3,[illegible]	[illegible],600	1,[illegible]
TOTAL	62,800	6,800	1,[illegible]	216,600	4,[illegible]0	[illegible],200	3[illegible]1,800	3,500	[illegible]	[illegible],400	3,1[illegible]	[illegible]

1/ Acre-feet.
2/ Total Dissolved Solids.
3/ Milligrams per liter.
4/ Data for quantity and TDS in the San Luis Service Area were obtained from the United States Bureau of Reclamation.

Figure 4. EIGHT STUDY ZONES IN THE DRAINAGE PROBLEM AREAS

Figure 5 ESTIMATED QUANTITY AND WEIGHTED QUALITY OF WATER DISCHARGED INTO THE SAN JOAQUIN MASTER DRAIN



Department of Water Resources San Joaquin District 1965

The salt routing technique traces the water used for agriculture in a given area through the soil profile into a drain or into the deeper ground water. This work was based on salt leaching equations developed for the study zones and digital models that have been developed to explain the behavior of water in a ground water basin. There are two sources of salts in the soil profile: those concentrated by evapotranspiration and those deposited by nature. Excess irrigation water percolates through the soil profile and leaches these salts into the subsurface tile drains or deeper ground water. The water and salt collected in the drains may either be recirculated in a diluted form as water supply or discharged into the Master Drain. Appendix E (Drainage Requirements) of Bulletin 127 presents detailed discussions of the salt routing technique.

Water Quality Surveillance Studies

The water quality surveillance studies utilized the water quality constituents and the drainage problem area boundaries established by the salt routing technique. Through an extensive sampling program from May 1959 to October 1964, data were gathered which made possible estimating concentrations of the major constituents which will be present in the drainage waters from the previously mentioned zones. Since October 1964, the sampling program has been continued to determine any possible water quality changes, but is not as extensive as in previous years. The results of this program were analyzed and correlations were made between the individual constituent and electrical conductivity.

Total Dissolved Solids

The total dissolved solids (TDS) in water are determined by three commonly used methods: (1) evaporation of known volume of water sample and weighing of the residue; (2) the summation of selected constituent concentrations; and (3) the specific conductance (electrical conductivity, EC). The specific conductance is measured in millimhos per centimeter at 25° C (EC x 10^3) or micromhos (EC x 10^6). One millimho is approximately equivalent to 10 equivalents per million (epm). By measuring EC and determining the TDS for a representative number of samples in an area, a correlation between TDS and EC can be established. Measuring EC to determine the approximate TDS is the most practical and economical method of determining the TDS for a large number of samples. Figure 6 shows the TDS/EC relationships found for five of the eight study zones.

Figures 6 through 16 present data from Zones I, II, IV, V, and VI. The data from Zones III, VII, and VIII were too limited to determine an adequate correlation.

Effluent samples were collected and analyzed from 15 subsurface tile drainage systems in Zone IV. This area has

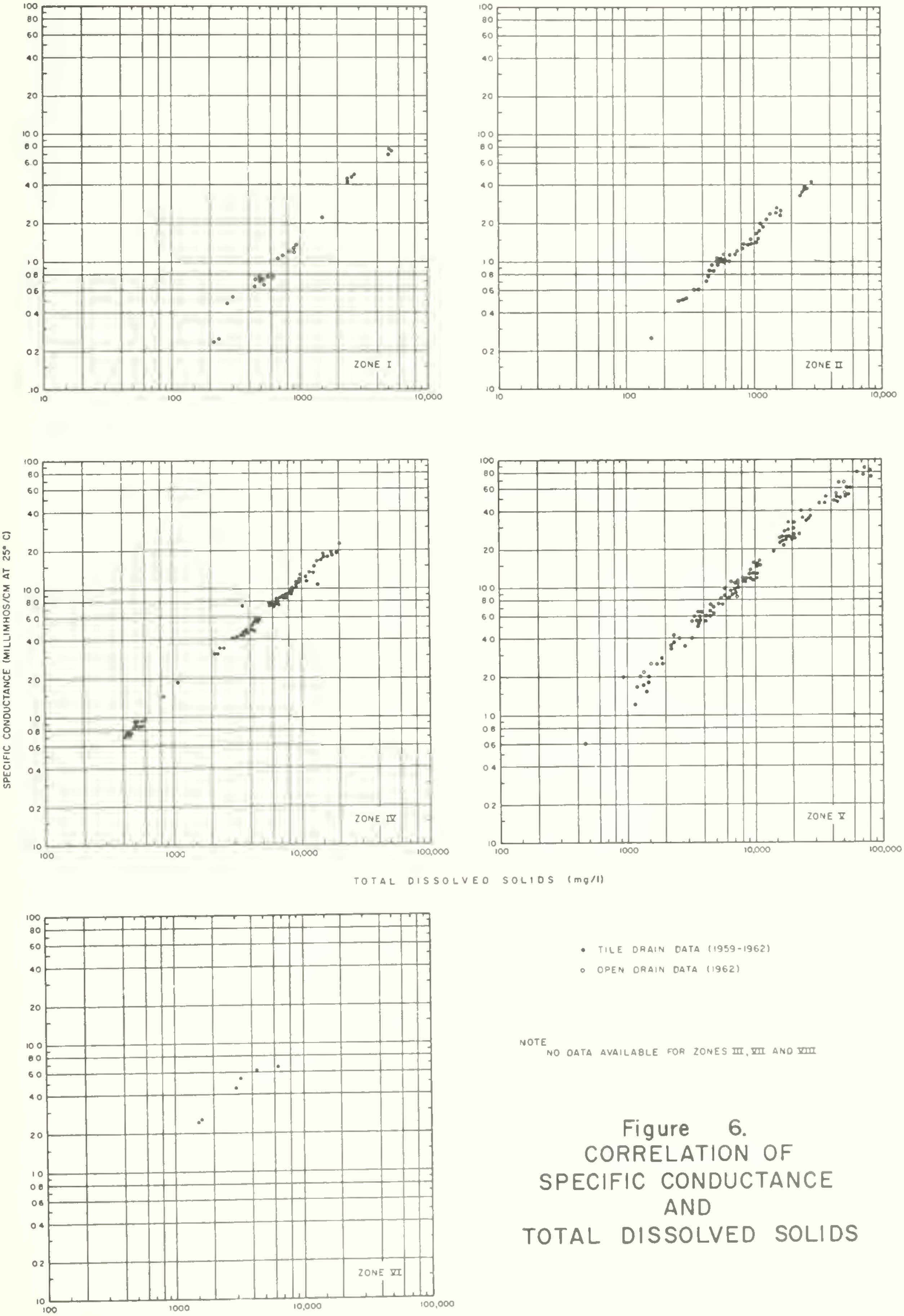


Figure 6.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
TOTAL DISSOLVED SOLIDS

been extensively irrigated for almost 35 years. Subsurface tile drainage systems were installed as early as 1951, and their use since then has increased almost every year. A leaching equation developed for these 15 subsurface tile drainage systems expressing electrical conductance and time was developed for this zone as $Y = 11.74\ X^{-0.30}$ (Correlation Coefficient = 0.57), where Y is the effluent electrical conductivity in millimhos per centimeter at 25^{o} C, and X is the system age in years.

Major Dissolved Solids

The total dissolved solids concentration primarily consists of the combination of nine major ions. The cations are calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), and potassium (K^{+}); while the anions are carbonate (CO_3^{--}), bicarbonate (HCO_3^{-}), sulfate (SO_4^{--}), chloride (Cl^{-}), and nitrate (NO_3^{-}).

Correlations between specific conductance and most of the major cations and anions were established. Figures 7 through 15 present the relationships found for specific zones. A relatively high degree of correlation existed between EC and Ca, Mg, Na, SO_4, and Cl when a substantially large number of samples were involved. No apparent correlation existed between EC and the K, HCO_3, and NO3 concentrations. There were only a few analyses that contained any measurable concentrations of CO_3; therefore, it was not realistic to construct a plot of CO_3 versus EC. One factor contributing to this apparent lack of correlation is that numerous living organisms utilize these ions in their metabolism.

Calcium (Figure 7) is found in nearly all natural water, soil, plant tissue, and animal bone. It is essential to normal plant growth and if not sufficiently supplied on agricultural lands by irrigation water, it is generally supplemented in the form of gypsum ($CaSO_4$). A calcium soil is friable and therefore easily worked, permits water to penetrate readily, and does not run together or puddle when wet. Salts of calcium vary greatly in solubility.

Magnesium (Figure 8) although not as abundant as calcium in nature, has very similar properties to those of calcium. It is an important constituent of the chlorophyl in green plants and is an essential plant nutrient. Magnesium was found in all the agricultural waste waters sampled.

Sodium (Figure 9) is widely distributed and is the most abundant cation found throughout the areas under investigation. Unfavorable soil conditions result when sodium is the predominant cation, since this type of soil tends to become impervious and thus undesirable for crop production. Most plants develop normally with little or no sodium available. Reclamation of alkali soils (sodium the predominant cation) involves the replacement of adsorbed sodium by calcium or

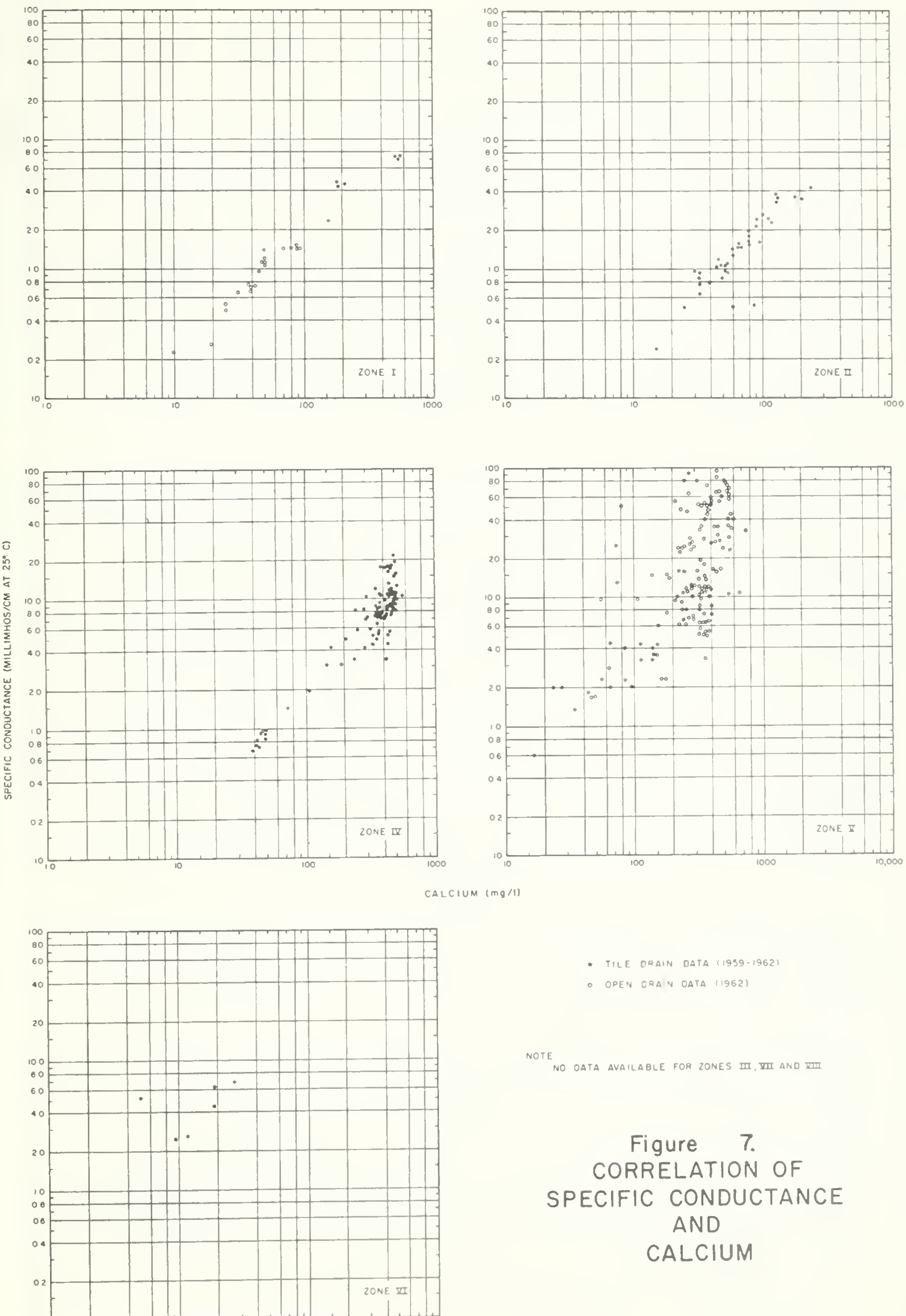


Figure 7.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
CALCIUM

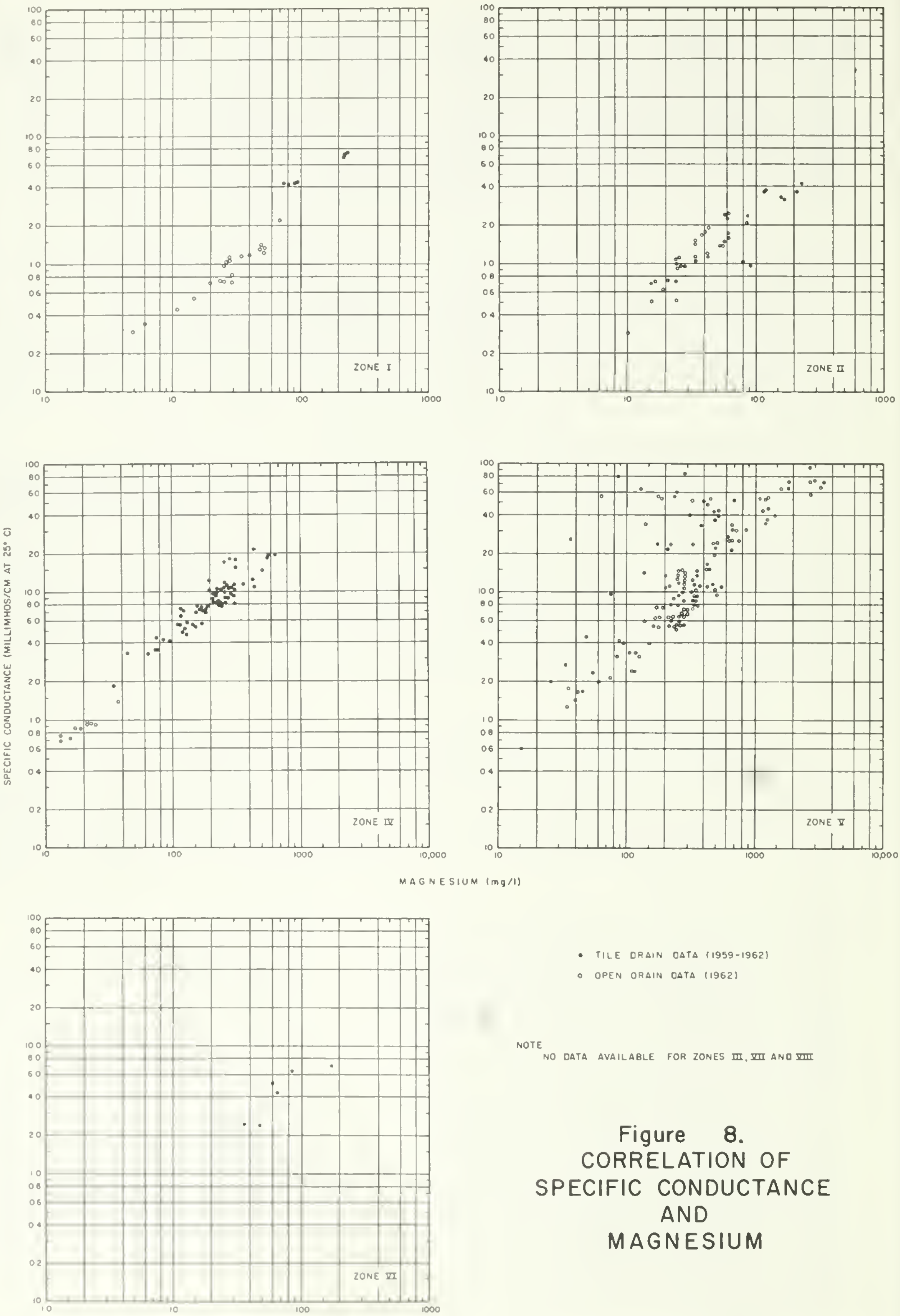


Figure 8.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
MAGNESIUM

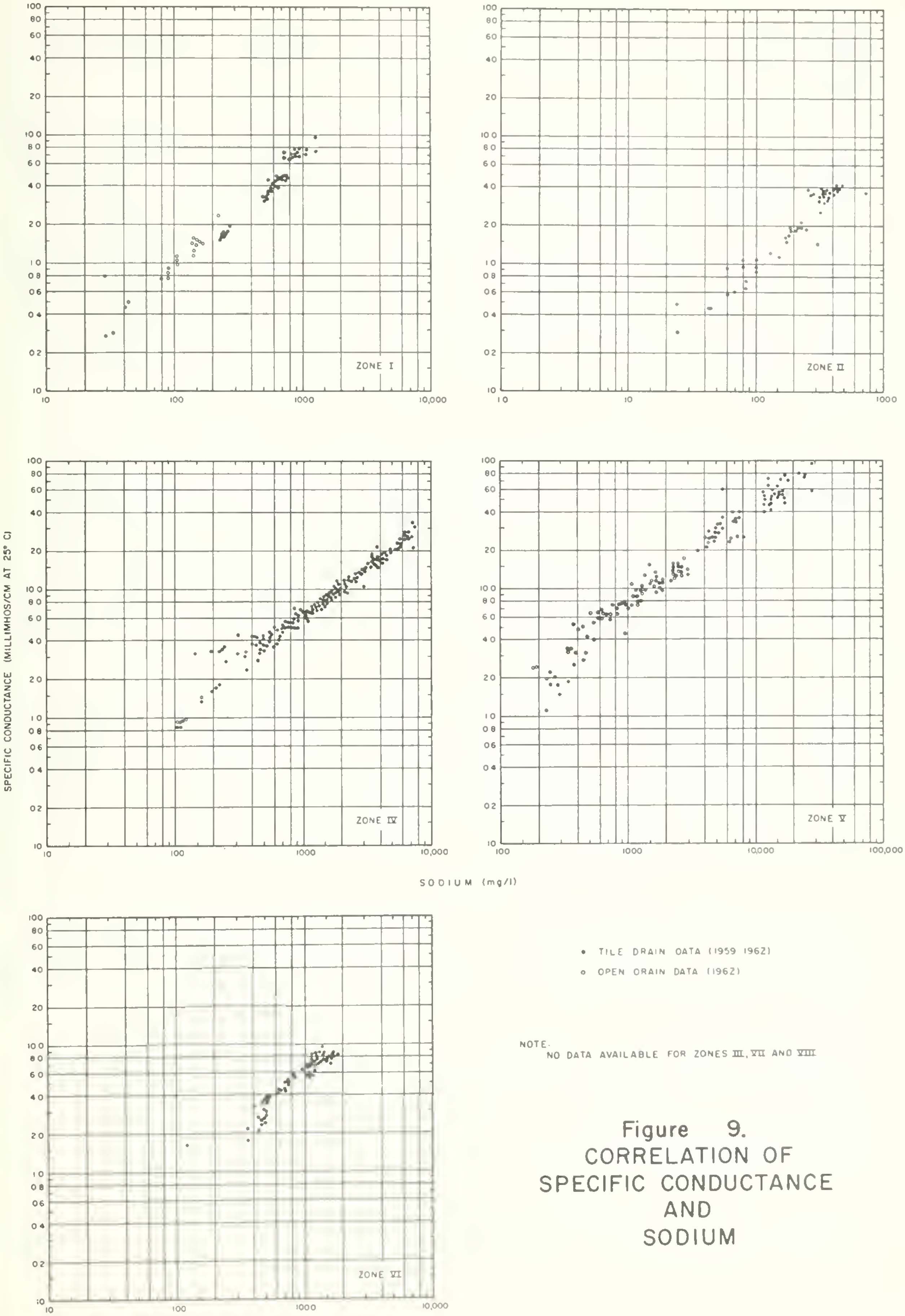


Figure 9.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
SODIUM

magnesium and the subsequent removal of sodium by leaching. Gypsum is the most common compound used for the reclamation of alkali soils.

The probable sodium concentration in the agricultural waste water of the San Joaquin Valley was found in the salt routing study to vary from zone to zone as well as to decrease with time, as shown in Table 12. Sodium concentrations were also estimated from the present agricultural waste water quality data consisting of measured concentrations of sodium ion in open drains, subsurface tile drainage effluents, and in some cases shallow ground water and soil extracts. The leaching equation developed for the sodium ions for Zone IV is $Y = 2289 X^{-0.44}$ (Correlation Coefficient = 0.56), where Y is the sodium concentration in ppm and X is the system age in years.

Sulfates (Figure 10) are most abundantly found in nature as a calcium salt. These salts are found in varying concentrations in both soils and water in the San Joaquin Valley. Sulfur, an essential element in plant nutrition is available to the land from gypsum and other common minerals. In high concentrations, sulfate may be toxic to plants. The variation of sulfate concentration with time, in Zone IV, is represented by its leaching equation $Y = 6015 X^{-0.33}$ (Correlation Coefficient = 0.60), where Y is sulfate concentration in ppm and X is the system age in years.

Chloride salts (Figure 11) are all water soluble. Because of this they are quite easily leached from soils. A limited amount of chloride is essential to plants and animals, but at high concentrations it inhibits the growth of most plants. Its leaching equation, as derived from Zone IV data, is $Y = 1115 X^{-0.39}$ (Correlation Coefficient = 0.54), where Y is the chloride concentration and X is the system age in years.

Potassium (Figure 12) has a number of chemical traits in common with sodium. However, potassium recombines more readily with other products of weathering, particularly clay minerals, than does sodium. Consequently, potassium is usually found in quite low concentrations in natural waters. Potassium does not show any relationship to electrical conductivity.

Carbonate, bicarbonate (Figure 13), and hydroxide each produce a condition known as alkalinity. Hydroxide, however, is rarely found in quantities capable of affecting alkalinity. Bicarbonate alkalinity is the predominant form whenever the pH of a sample is less than 9.5. Carbonates are essentially nonexistent for pH values of less than 8.3.

The term pH is the negative logarithm of the active hydrogen ion concentration and is used to express the strength of the acid or alkali in a water. The chemical test for

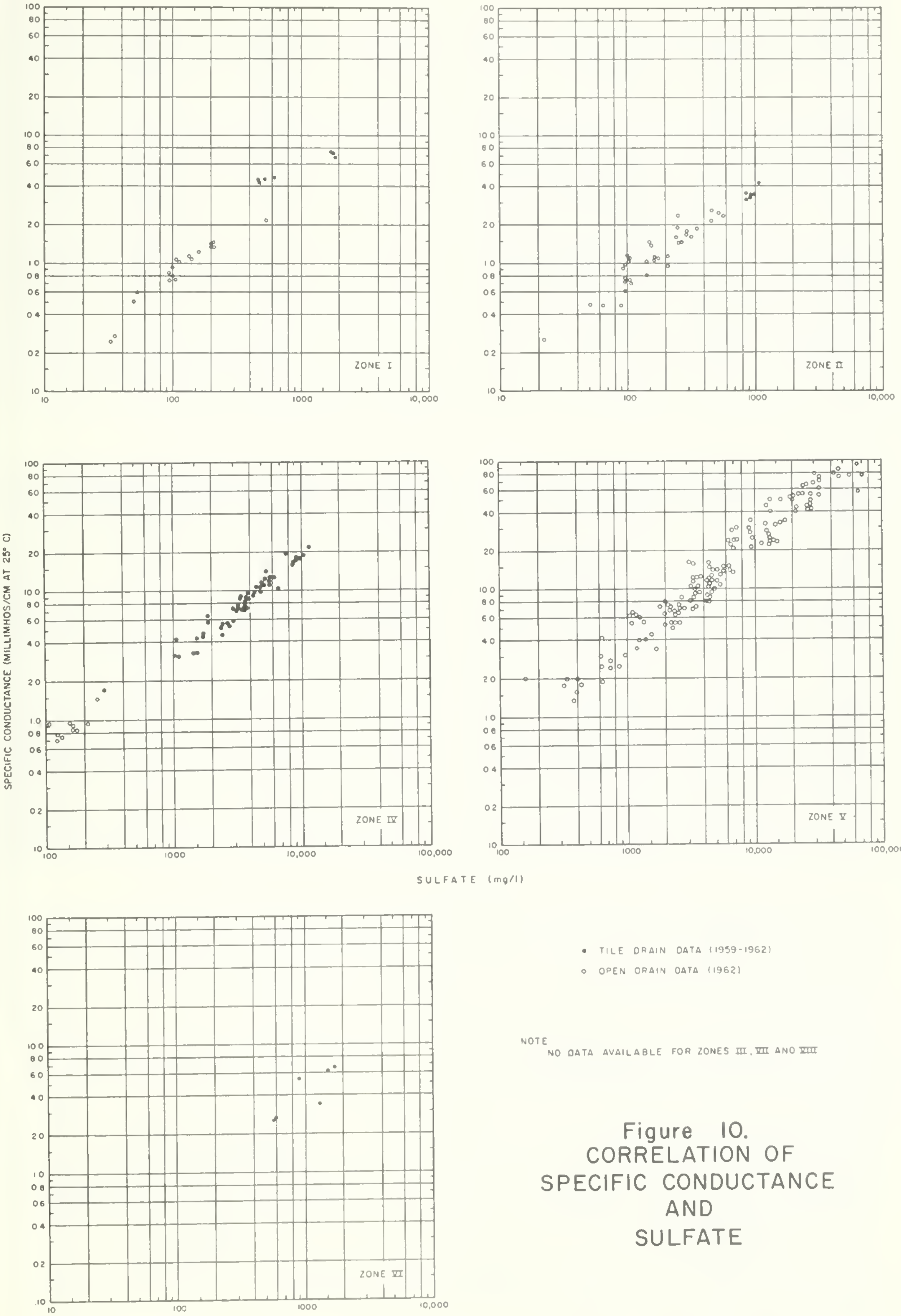


Figure 10.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
SULFATE

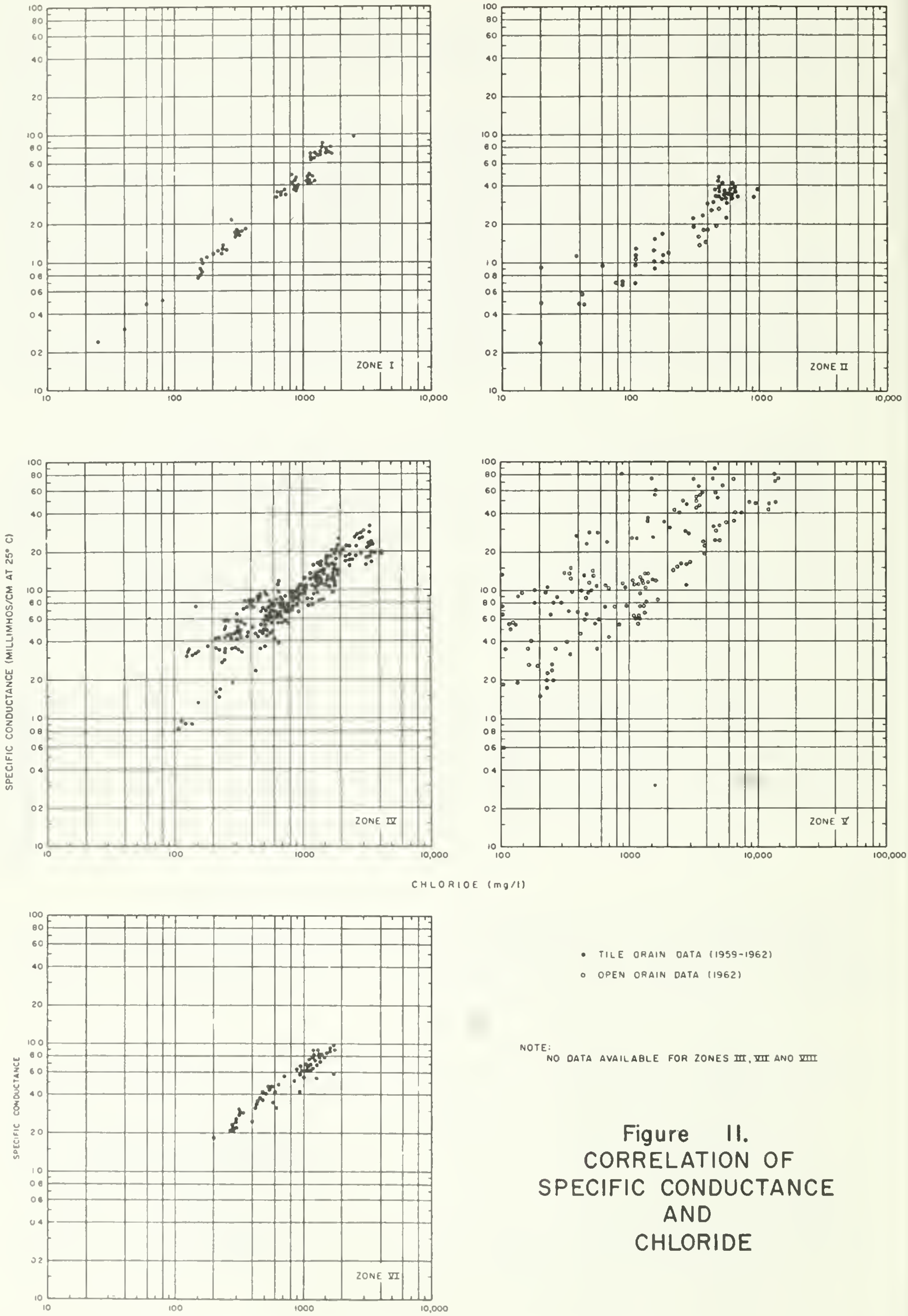


Figure 11.
CORRELATION OF SPECIFIC CONDUCTANCE AND CHLORIDE

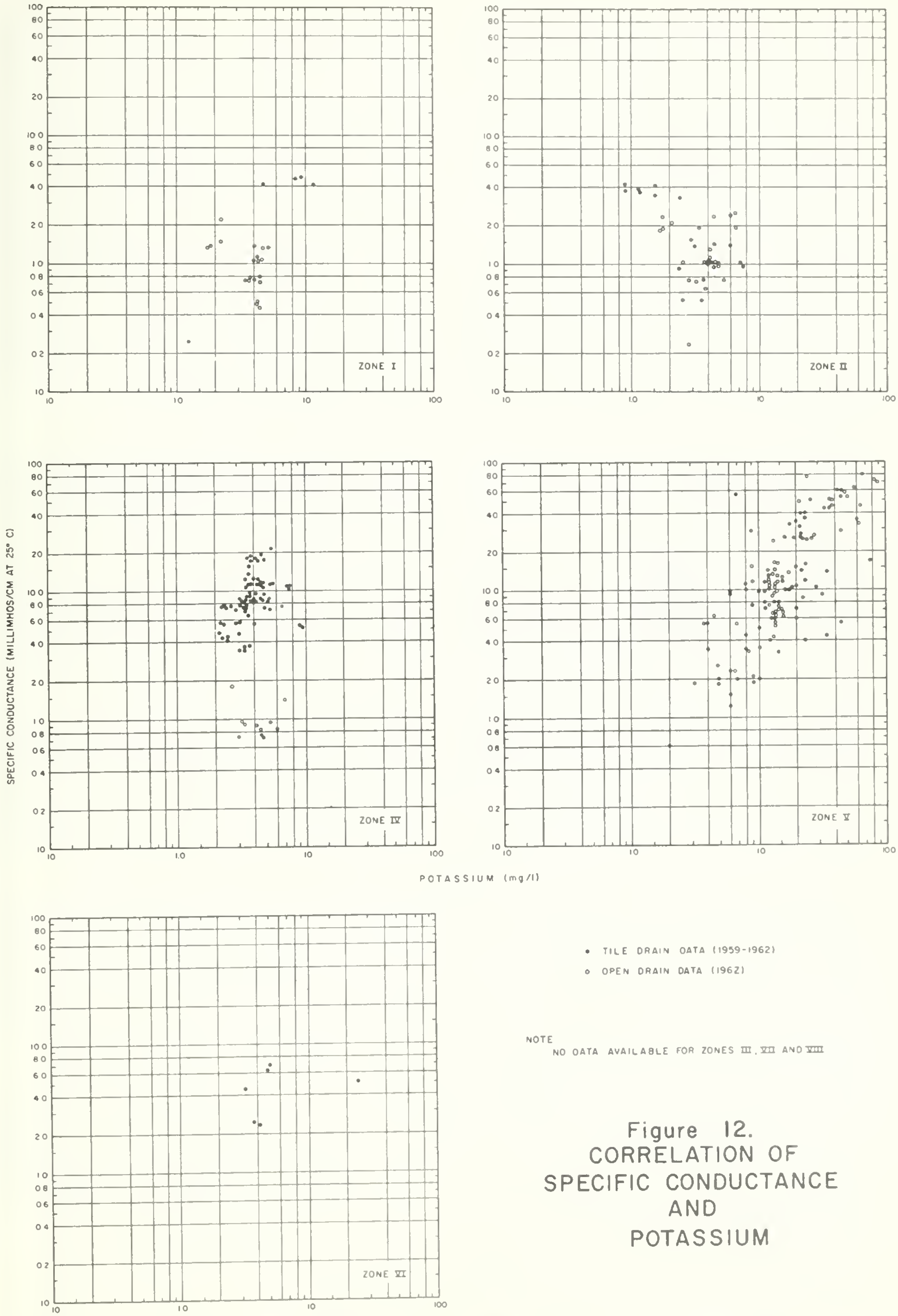


Figure 12.
CORRELATION OF SPECIFIC CONDUCTANCE AND POTASSIUM

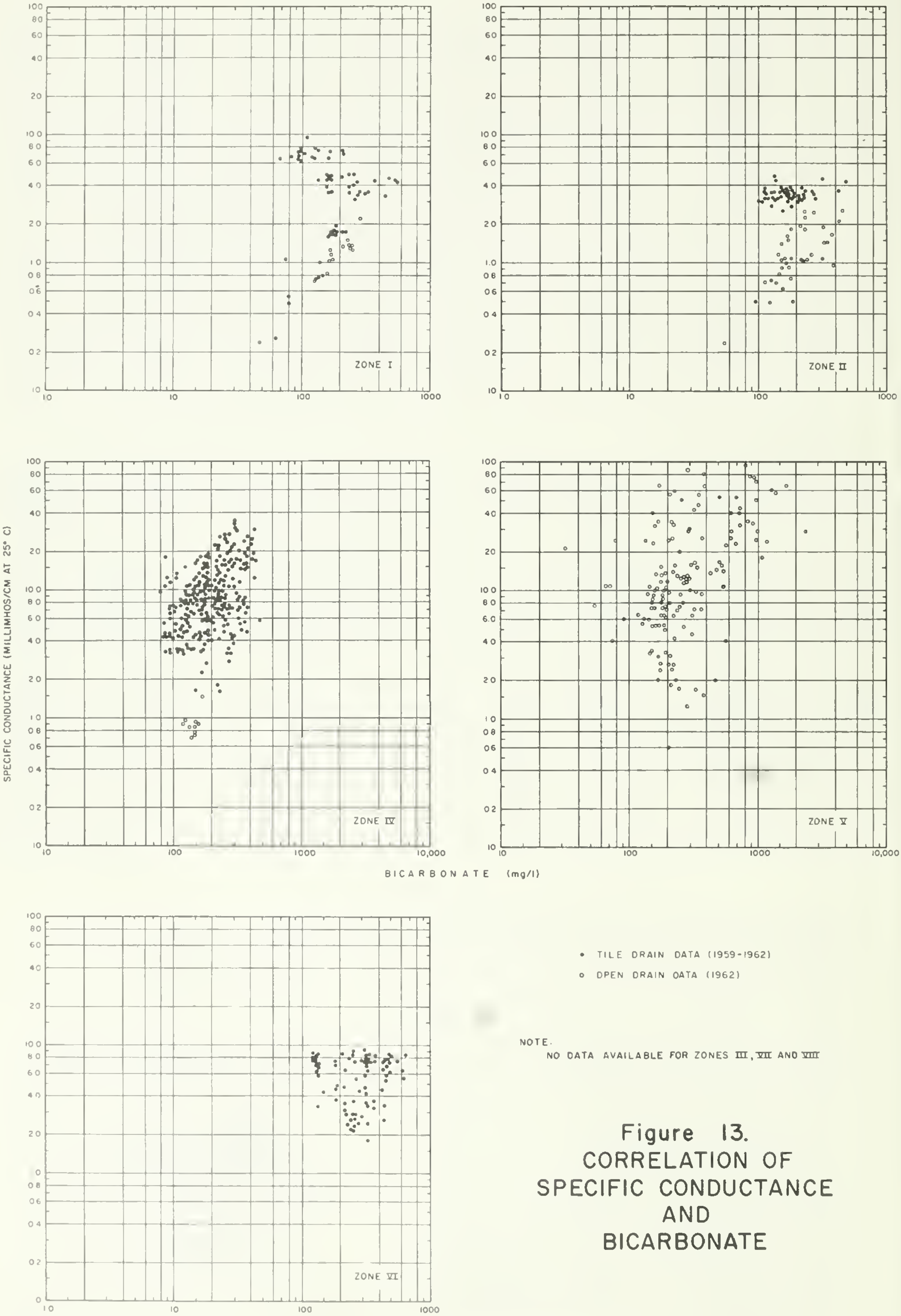


Figure 13.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
BICARBONATE

alkalinity determines the amount of alkali present. The end point for bicarbonate alkalinity is 4.5 on the pH scale. In irrigation water the bicarbonate ion itself does not cause any difficulty, but it aids in the precipitation of calcium carbonate and thus adversely affects the sodium balance.

Another characteristic of bicarbonate is that in the presence of cations it acts as a "buffer". The pH value of the water stays at equilibrium or at a reasonably constant level for a long period of time.

Carbonate salts were not found in any appreciable amount in the agricultural waste water analyzed as the pH values of the waters investigated generally were between 7.0 and 8.3 during the course of this investigation.

All nitrate salts (Figure 14) are soluble and easily removed by leaching. Fertile soil contains nitrate that results from oxidation of nitrogenous organic matter and from the fixation of atmospheric nitrogen by soil bacteria. When a land is deficient in nitrate and only traces of nitrates are present in the water supply, nitrogen-rich fertilizers such as aqueous ammonia are usually added as a supplement. Nitrate is a major factor in plant nutrition and, therefore, varies with the variety and quantity of plants present. No detectable correlation was found between nitrate and electrical conductivity. This is probably due to the role of nitrate in plant metabolism and its low concentration in comparison with TDS.

Hardness (Figure 15) is of special concern in domestic water supply since an increase in hardness will create the need for more soap before a lather can be formed. Hard water also forms sludge deposits or incrustations on surfaces with which it comes in contact and forms a hard scale in high temperature boilers.

Hardness is composed primarily of calcium and magnesium ions. Total hardness is composed of carbonate hardness and noncarbonate hardness. Carbonate hardness is caused mainly by carbonates and bicarbonates of magnesium and calcium, whereas noncarbonate hardness is caused by the chlorides, sulfates, and nitrates of magnesium and calcium. Carbonate hardness is referred to as temporary hardness and noncarbonate as permanent hardness.

As can be seen in Figure 15 total hardness varies with electrical conductivity. The leaching equation for total hardness from Zone IV is $Y = 49.04\ X^{-0.19}$ (Correlation Coefficient = 0.55), where Y is the total hardness in epm and X is the system age in years.

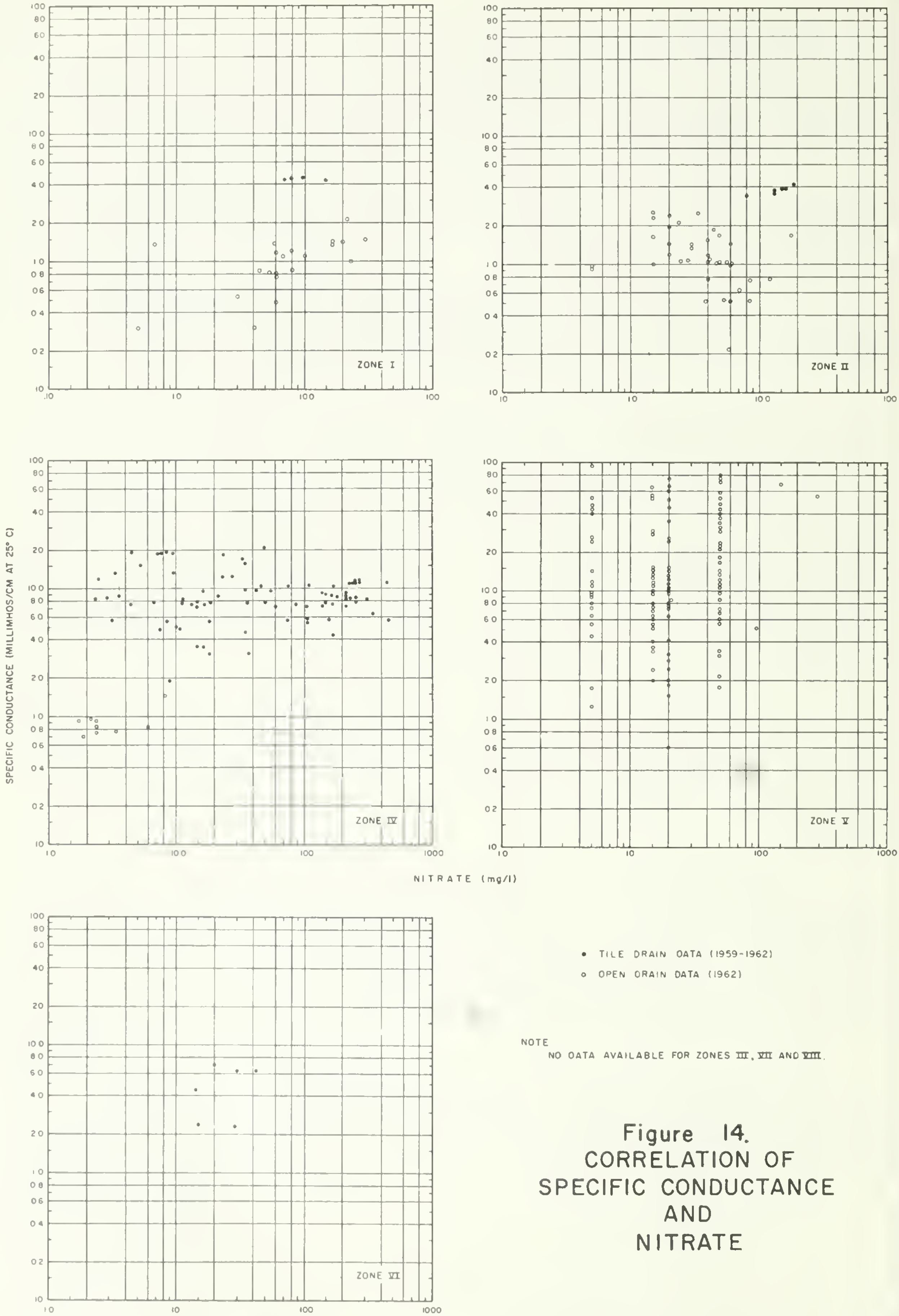
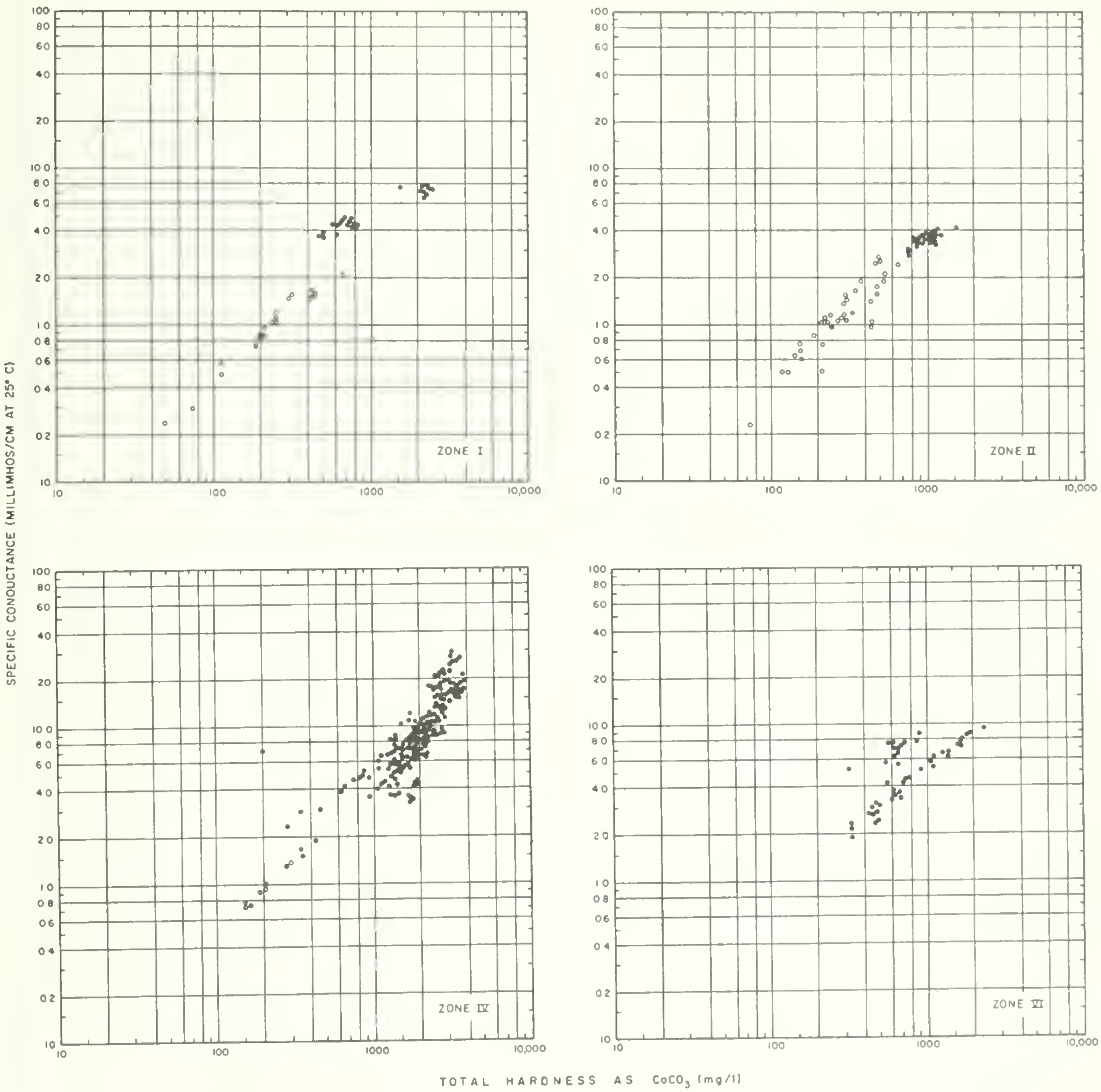


Figure 14.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
NITRATE



• TILE DRAIN DATA (1959-1962)

o OPEN DRAIN DATA (1962)

NOTE
NO DATA AVAILABLE FOR ZONES III, V VII AND VIII

Figure 15.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
TOTAL HARDNESS AS $CaCO_3$

Minor Dissolved Solids

The minor dissolved solids considered in this study are boron and silica. Boron (Figure 16) has been detected in the San Joaquin Valley agricultural waste water in concentrations of up to 200 ppm. In acid water, boron is generally in the boric acid (H_3BO_3) form. In alkaline water with pH below 9.2, both boric acid and tetraborate (B_4O_7) occur; and at a pH of 9.2 and above, only tetraborate is present. Most common compounds of boron are soluble in water. Traces of boron are essential to normal plant growth, but injury may occur for more sensitive plants in concentrations of more than one ppm. The result of the sampling of subsurface tile drainage system effluents in Zone IV showed a leaching relationship according to the following equation: $Y = 34.65\ X^{-0.59}$ (Correlation Coefficient = 0.65), where Y is the boron concentration in ppm and X is the system age in years.

Except for oxygen, silica is the most abundant element in the earth's crust. It may occur in natural waters in concentrations of 10 to 50 ppm and is generally considered to be of little importance in irrigation practice. Silica was formally included in the analysis of standard minerals since it is considered one of the constituents that compose TDS; however, silica is not usually a separate analysis if TDS is determined by evaporation.

Predictions of Constituent Concentrations in Master Drain

The methods used to estimate the future constituent concentrations from the results of the sampling program are explained in the following paragraph.

The chemical composition of drainage effluent that results after water is first applied to a soil column depends primarily upon the chemical composition of the soil. As time passes, many of the original salts undergo chemical change and are leached out of the soil by the applied irrigation water. After a sufficient period of leaching, the drainage water quality approaches the general chemical composition of the irrigation water, neglecting the effects of fertilizers and agricultural additives.

In the salt routing technique it was assumed that a passage of five pore volumes of water is required to leach the original salts from the soil column. The length of time to pass five pore volumes at field capacity varies depending on the permeability of the soil, water use, etc.

Predicted concentrations of constituents in the San Joaquin Master Drain are shown in Table 13. The concentrations predicted for 1970 were determined by using a weighted mean of the concentrations found in the soil and drainage samples taken in the identified drainage problem areas. As has been seen,

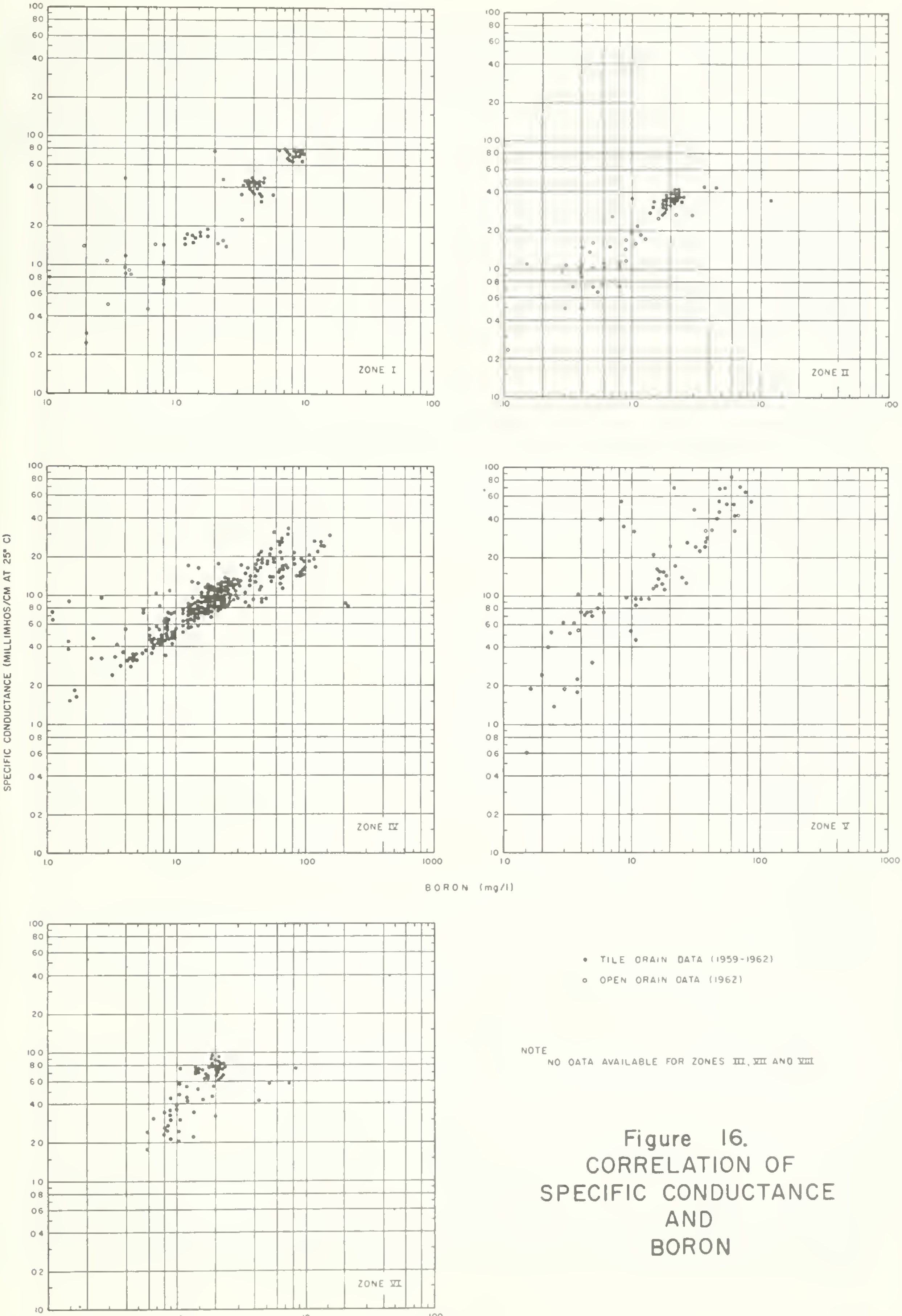


Figure 16.
CORRELATION OF
SPECIFIC CONDUCTANCE
AND
BORON

this water contains relatively large concentrations of sodium, sulfate, and boron. Two different methods were utilized to predict the concentration of the constituents in drainage waters after 50 years of operation (2020) of the Master Drain. The first method is based on the quality of the applied waters. The average concentration of the constituents in the samples of supply water was considered to be representative. These values were then assumed to be concentrated by evapotranspiration to a point where the total dissolved solids (TDS) concentration reached 2,500 parts per million. The other method combined the results of the salt routing technique studies (TDS and sodium concentrations) with estimates of the remaining constituents made by applying the leaching equations developed from the surveillance program.

Table 13

PREDICTED CONCENTRATIONS OF CONSTITUENTS IN THE SAN JOAQUIN MASTER DRAIN
Expressed in milligrams per liter (ppm)

Constituent	Year 1970 Expected	2020 Method 1	2020 Method 2	2020 Expected
Specific Conductance (micromhos at 25° C.)	8,750	3,500	3,500	3,500
Total Dissolved Solids	6,800	2,500	2,500	2,500
Major Cations:				
Calcium	220	200	160	160
Magnesium	160	120	90	90
Sodium	1,900	420	540	540
Potassium	20	30	10	10
Major Anions:				
Carbonate	0	0	0	0
Bicarbonate	220	200	200	200
Sulfate	3,500	580	1,190	740
Chloride	1,000	830	340	670
Total Nitrogen as NO_3	90	10	90	90
Boron	11	2	3	3
Percent Sodium	77	47	60	60
Hardness as $CaCO_3$				
Total	1,200	1,000	770	770
Noncarbonate	1,000	840	610	610

The future constituent concentrations determined by the two methods were combined to arrive at the "expected" quality. The "expected" cation concentrations are the same as those predicted by the second method. This was done because of the nature of the methods. The salt routing studies were more detailed than the survey of irrigation water in this area. The anion concentrations, however, were determined as being equal to a weighted mean of the values determined by each method. The reasons for this are presented in the following paragraphs.

The San Joaquin River drainage basin is expected to contribute approximately 60 percent of the total amount of water in the Drain in 2020. Most of the identified problem areas in the basin are estimated to have passed at least five pore volumes by 2020 so that the drainage from this basin should have the same general chemical composition as the irrigation water.

The Tulare Lake drainage basin is expected to contribute approximately 40 percent of the total drain quantity in 2020. In the lakebed area, it is estimated that it will take about 80 years to pass five pore volumes. The rest of the basin is not expected to receive drainage service until 1980 or after, and thus five pore volumes will not have passed through it by 2020. Therefore, approximately 40 percent of the total drain quantity will still be reflecting the chemical composition of the soil.

Table 14 presents constituent concentrations that are not expected to vary with time. These values represent the arithmetic mean of analyses performed on subsurface tile drainage effluents. Nitrogen and phosphate concentrations may vary with the amount of leaching and the amount and kind of fertilizers, however, the maximum phosphate concentration will be quite low because of low solubility of phosphates in neutral or slightly alkaline solutions. The remaining constituents of Table 14 do not appear to vary appreciably with leaching.

Ground water quality was considered in the salt routing technique but was not considered in the water quality surveillance program because it had been used in establishing the water quality indicators for the salt routing technique, and the accuracy involved in trying to include it to estimate the individual major constituents was questionable.

Factors such as land modifications, changing agricultural practices, and sources of water supply are considered to follow a predetermined trend; nevertheless, changes in these factors could have a pronounced effect on the waste water quality. The numerous interdependent variables involved in irrigation cycles are very complex and are not fully understood. Therefore, the computed and predicted values contained in this appendix are based on a weighted average of the present available data on agricultural waste water quality, predicted population, increase in imported water, land development, plus an intermingling of engineering judgment.

TABLE 14

ESTIMATED CONCENTRATIONS OF CONSTITUENTS
NOT EXPECTED TO VARY IN
THE SAN JOAQUIN MASTER DRAIN

Constituent	Parts per Million
Total Nitrogen	21
Total + Organic Phosphate	0.35
Pesticides	<0.001
Dissolved Oxygen	5-10
5-day Biochemical Oxygen Demand (BOD)	1-3
Chemical Oxygen Demand (COD)	10-20
Surfactant (ABS)	<0.01
Phenolic Materials	0.001
Grease and Oil	0.5

CHAPTER VI
TREATMENT AND DISPOSAL

The investigation of the water quality aspects of the San Joaquin Master Drain has determined that most if not all of the waste water in the Master Drain will be agricultural subsurface drainage water. The main reasons for this, as previously explained, are economics and need. The estimates of the quality of waste water in the Drain were made taking this fact into consideration. The Drain is basically designed to accept all unmodified subsurface agricultural waste waters that have been degraded to a point beyond which they cannot be physically or economically reused for agricultural purposes. All material to be discharged into the Master Drain must meet specified criteria that were adopted by the Department in June 1966. The criteria for acceptance of waste water were part of an "Application for Waste Disposal Service" that the Department sent to potential Drain users in October 1966. The criteria are quoted below.

CRITERIA FOR ACCEPTANCE OF WASTE WATER
into the
SAN JOAQUIN MASTER DRAIN

1. POLICY.

The capacity of the San Joaquin Master Drain is intended to be reserved for subsurface agricultural waste water. Other wastes may be discharged into the drain in unusual circumstances. In no case will other discharges be allowed that degrade the waters in the Master Drain or prevent meeting the discharge requirements for the Master Drain. It is intended that all San Joaquin Valley waste waters shall be used and reused to the maximum extent practicable before discharge into the Master Drain.

2. AGRICULTURAL WASTE WATER.

a. Subsurface.

The acceptance of subsurface agricultural waste water *(which means water which has been applied as irrigation water and which has been collected, after percolation, by subsurface drains)* shall be subject to the following limitations:

(1) The waste water shall have a minimum total dissolved solids concentration of 900 milligrams per liter until the Central Valley Regional Water Quality Control Board, hereinafter referred to as the Board, establishes requirements for the discharge of agricultural waste water into the San Joaquin River. The minimum total dissolved solids shall then be revised to be equal to or less than the maximum established for discharge to the San Joaquin River.

(2) The waste water shall not have been concentrated by ponding for more than one day.

(3) The waste water shall not have been diluted by surface waters.

(4) Waste water not meeting the limitations set forth herein above may be accepted if:

(a) The boron concentration exceeds five milligrams per liter; or

(b) the chloride concentration exceeds 500 milligrams per liter; or

(c) other substantiated reasons, acceptable to the State, prevent water reuse.

b. Surface.

Surface agricultural waste water shall be used and reused to the maximum extent practicable, but based on the individual circumstances may be accepted into the Master Drain if they conform to the quality limitations for subsurface agricultural waste water.

3. NONAGRICULTURAL WASTE WATER.

The following *guidelines* will be used in determining if nonagricultural waste water is acceptable. Approval to discharge such water into the Master Drain shall be based on the individual circumstances and shall be revocable upon reasonable notice.

The *guidelines* for acceptance of such waters are:

(a) The quantity shall not exceed one percent of the capacity of the reach into which it discharges.

(b) The total dissolved solids shall not exceed the Board's terminal discharge requirements for the Master Drain.

(c) The Immediate Oxygen Demand shall be zero.

(d) The pH shall be between 6.5 and 8.5.

(e) The waste water shall neither cause nor contain any of the following:

(1) Sludge deposits.

(2) Visible oils and greases.

(3) Objectionable odors.

(4) Unsightliness.

(5) Other nuisance conditions.

(f) Settleable solids shall not exceed 0.5 milliliter per liter per hour.

(g) The waste water shall not contain concentrations of constituents that are detrimental to human, animal, fish or aquatic plant life or to the operation of the Master Drain.

(h) The waste water shall not contain any corrosive wastes.

(i) The waste water shall not contain nitrogen in excess of 20 milligrams per liter.

(j) The waste water shall meet criteria for water contact sports as may be defined by the State Health Department.

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Table 15 presents the estimated effects of Master Drain discharge on the San Joaquin River water quality near the Antioch Bridge. These estimates were made by combining predicted drain discharge quality (Tables 13 and 14) with the results of dye dispersion studies that have been conducted in the estuary during the "Delta-Suisun Bay Water Quality Investigation". Excluding nitrogen it appears that there will not be any significant problems as a result of the Drain discharging at Antioch Bridge.

One of the main reasons why the constituents of the Master Drain will have such a negligible effect on the receiving waters is that in the summer when the salt concentrations in the receiving waters are generally maximal, due to salinity intrusion, the quantity of flow in the Master Drain will be maximal, whereas in the winter when the salt concentrations in the receiving waters are generally minimal the quantity of flow in the Master Drain will be minimal.

The predicted pesticide content of the Master Drain is in the same general range as that found in the waters of estuary and ocean. This range is currently considered by most authorities to be far below the known tolerance level for living matter.

The major area of concern in the water quality spectrum is the possible excessive algal growth in the Master Drain and/or receiving waters. As previously mentioned two of the main nutrients required for algal growth are nitrogen and phosphorus. The concentration of phosphorus in the Master Drain will be approximately equal to that of the receiving water and will therefore not cause any problem in the Delta-Bay system. The nitrogen concentration however, is a different story, as is seen in Table 15. Since the nitrogen concentration of the drain water will be significantly higher than that of the receiving water, it will cause concentration increases in the San Joaquin River once discharged into it. The significance of these predicted nitrogen concentration increases in the receiving waters is still a matter of conjecture.

Water quality control policy for the Sacramento-San Joaquin Delta was adopted by the State on June 14, 1967. This and other policies were submitted to the Secretary of Interior as proposed federal water pollution control standards pursuant to the provisions of the Federal Water Pollution Control Act. The Federal Water Pollution Control Administration (FWPCA) felt that all of the beneficial uses were not adequately protected. As a result of an FWPCA proposal, the State Water Resources Control Board adopted supplemental water quality control policy (Resolution 68-17) on October 24, 1968. Several steps are being taken to make sure that the discharge from the drainage facilities will not violate these water quality objectives. Generally, these steps are as follows: construction of the drain in phases, a system of discharge control works, an extensive surveillance program, and treatment if necessary. If it

TABLE 15

ESTIMATED MAXIMUM EFFECT OF THE SAN JOAQUIN MASTER DRAIN ON THE SAN JOAQUIN RIVER NEAR ANTIOCH

	1970		1995	
	Summer	Winter	Summer	Winter
	Flow in cubic feet per second			
Master Drain	150	25	915	350
San Joaquin River	500	8,000	1,000	3,500
	Total Dissolved Solids in parts per million (TDS)			
Master Drain	6,800	6,800	3,300	3,300
S. J. River	2,900	200	7,100	180
S. J. River + Master Drain	2,970	206	6,800	236
% Increase	2	3	-4	31
	Chloride in parts per million (Cl)			
Master Drain	1,000	1,000	730	730
S. J. River	1,490	55	3,710	45
S. J. River + Master Drain	1,480	56	3,480	57
% Increase	-1	2	-6	27
	Sulfate in parts per million (SO_4)			
Master Drain	3,500	3,500	1,260	1,260
S. J. River	265	20	645	15
S. J. River + Master Drain	322	23	693	37
% Increase	21	15	7	147
	Sodium in parts per million (Na)			
Master Drain	1,900	1,900	800	800
S. J. River	770	30	1,930	25
S. J. River + Master Drain	790	32	1,840	39
% Increase	3	7	-5	56
	Boron in parts per million (B)			
Master Drain	11	11	4.5	4.5
S. J. River	0.15	0.15	0.15	0.15
S. J. River + Master Drain	0.34	0.16	0.49	0.23
% Increase	127	7	226	53
	Total Nitrogen in parts per million (N)			
Master Drain	21	21	21	21
S. J. River	1.5	1.5	2.0	2.0
S. J. River + Master Drain	1.8	1.5	3.5	2.3
% Increase	20	0	75	15

appears that none of the steps is going to be adequate, the discharge facility will be moved to a more favorable location.

The construction of the drainage facilities will be accomplished in phases, as will the tie-ins to the various sources. The first segment of the San Luis Drain is under construction by the USBR and will include a reservoir. All of the waste water entering the San Luis Drain during its first two years of operation will be stored in the reservoir. The completed San Luis Drain should start discharging near Antioch Bridge in 1972. The full capacity of the San Luis Drain will not be required for many years after its completion.

Besides holding the waste water delivered to the San Luis Drain prior to the completion of the discharge structures, the reservoir could be used to hold back wastes when it is unadvisable to discharge. At times when the release of drain water may have an adverse effect on beneficial uses of the San Joaquin River it would be held in storage.

Investigations of several aspects of the Delta and Bay have been and are presently being conducted by many separate agencies. The USBR and DWR have established a surveillance program to monitor representative stations in the Delta and Bay to obtain background information before the San Luis Drain begins to discharge into the system and will continue to monitor these stations to ascertain if drainage facilities create any adverse conditions in the receiving waters. This program will measure the slightest changes in constituent concentrations, and changes in operation of the drainage facilities will be geared to it.

Because of the possibility of nitrogen concentrations causing a biological problem and the unknown effects of pesticides in natural waters, the Department of Water Resources commissioned three consultants from the University of California to study and report on the feasibility of removing pesticides and AGP from the San Joaquin Valley's drainage waters. This group was known as the Biological Treatment Consulting Board. A report of the findings and recommendations of this Board was presented to the Department in March 1964. The recommendations are quoted below.

Recommendations of the Biological Treatment Consulting Board

1. San Joaquin Valley waste waters should be treated to remove algae growth potential, particularly as the Master Drain approaches its peak discharge rate.

2. A small pre-pilot plant (50 by 200 feet) should be established in a drainage area to serve as a guide to the design of two larger pilot plants.

a. This pre-pilot plant should be located at a point where typical drainage water is available for its operation.

b. It should be operated to determine:

(1) The rates of production of algae in drainage water and the types of algae produced.

(2) The removal of algal growth potential from drainage waters by pilot plant processing.

(3) The composition of algae produced; its digestibility, and its protein and heavy metal content.

(4) Depths and detention periods and other design criteria for the larger plants as given in Recommendation 5 below.

(5) A modus operandi for the large plants as given in Recommendation 5 below.

3. A study should be made of the ecological relation between biota in the Bay and those in the Master Drain to arrive at information that would be of value in predicting the time and degree of urgency for the provision of a waste water treatment system.

4. A research study, the goal of which would be the perfecting of methods and economics of algae separation, should be conducted in conjunction with the existing University of California pilot plant, so that the most economical of the available separation processes may be installed in the two pilot plants.

5. Following the preliminary studies summarized in items 2 and 4 above, two 1-million-gallon-per-day pilot plants should be constructed and operated to study:

a. Algae growth in drainage waters.

b. Water quality following algal growth.

c. Design and operational parameters for the master drainage treatment plant.

d. Methods for increasing the production of algae and the effectiveness of stripping.

e. Uptake of pesticides by algae growing in drainage waters.

f. Methods of physical, chemical, and biological separation of algae.

g. Methods of processing algae.

6. The algae harvested as a part of the operation of the pilot drainage treatment plant should be utilized in a study to determine:

a. The value of the product as a foodstuff and raw material.

b. The production of energy by way of the anaerobic digestion of harvested algae and the application of this energy to desalination of drainage waters for reuse.

c. Its pesticide content.

d. Its heavy metal content.

e. Its part in the accumulation and dispersion of pesticides.

*

8. Precise methods should be developed for the qualitative and quantitative determinations of pesticides in drainage waters and in algae.

9. A field laboratory should be established in the vicinity of the Master Drain discharge in order to make possible a continuing study of the physical, chemical, and biological impact of the Master Drain upon the environment.

10. A research advisory board should be retained to assist the Director in implementing and guiding the above program during its initial stages.

The Department is using these recommendations as guidelines whenever practicable. Mr. William J. Oswald acted as a consultant in the design and construction of the pre-pilot plant.

In January 1967, the Department of Water Resources, the Federal Water Pollution Control Administration, and the Bureau of Reclamation joined in a three million dollar, three-year study of nitrogen removal from agricultural waste water. This study is the result of FWPCA's report, "Effects of the San Joaquin Master Drain". Nitrogen removal treatment studies are being conducted at the Agricultural Waste Water Treatment Center approximately two miles west of Firebaugh in Fresno County. In addition to the studies in the pre-pilot plant, nitrogen removal by bacteriological denitrification is being studied in deep ponds and filters. A final report published at the conclusion of the treatment studies will summarize the results.

*Item 7 was missing in the original report.

The final report will establish the economics of treatment and discharge to the San Francisco Bay system versus rerouting and the discharge of untreated wastes to the Pacific Ocean.

A Drainage Treatment Consulting Board has been established to advise on the studies at the Agricultural Waste Water Treatment Center. The Board consists of Dr. William J. Oswald and Dr. Clarence G. Golueke of the University of California, and Dr. Perry L. McCarty of Stanford University.

CHAPTER VII
SUMMARY

The purpose of this appendix is to report the results of water quality studies that were part of the San Joaquin Drainage Investigation. The objectives of the water quality studies were to determine the present and predict the future quality of agricultural waste water; evaluate the significance of the probable effects of the drain discharge on the receiving waters and investigate the need for treatment of the Master Drain effluent; and appraise the results both within the Master Drain and in the receiving waters by the acceptance or rejection of municipal, industrial and oilfield waste waters.

The area of investigation comprises the San Joaquin Valley's entire eight million acres, 90 percent of which is irrigable. The Drain is basically designed to accept all unmodified subsurface agricultural waste waters that have been degraded to a point that they cannot be physically or economically reused for agricultural purposes. Municipal, industrial and oilfield waste waters may be accepted in the San Joaquin Master Drain provided that they meet specified criteria; however, it is not considered economically justifiable to treat and transport municipal or industrial waste waters long distances to the Master Drain. If any municipal or industrial waste waters are ever discharged into the Master Drain, they would have to have their origin near the Drain's alignment and be adequately treated for protection of the discharge area.

The major quantity of municipal and industrial waste water is located on the east side of the San Joaquin Valley, whereas the Master Drain will be located on the west side of the Valley. Therefore, the cost of transporting these wastes to the Drain, along with that of the additional treatment that would generally be required prior to acceptance to the Drain makes it evident that little if any of these wastes will be discharged into the Drain.

Oilfield waste waters on the east side of the Valley are of such a quality that the majority of it is used for irrigation; whereas the waste waters on the west side of the Valley are of very poor quality and not used for irrigation. However, as with the municipal and industrial wastes, it was concluded that it would not be economically justifiable to convey oilfield wastes to the San Joaquin Master Drain; considering the treatment necessary for acceptance, the expense of conveyance, and the numerous disposal methods already in use.

The present and future quality characteristics of the agricultural waste water of the San Joaquin Master Drain were determined through utilization and evaluation of two major studies: the salt routing technique and water quality surveillance study. The salt routing technique followed a unit quantity of water from the time it was applied to the land until it was no longer usable for agricultural purposes. The quantity, and T.D.S. and sodium concentrations in the waste water in different portions of the Valley were determined by this method. The results of the water quality surveillance study were employed as a basis for the determination and prediction of the other constituents that characterize the quality of the San Joaquin Valley waters. These two studies enabled the Department to estimate the quality of water in the Master Drain from 1970 to the year 2020.

Nutrient supplements in the form of fertilizers are used to promote the growth of agricultural crops. The main element in most fertilizers is nitrogen, with phosphorus also being used in a high percentage of cases. Other nitrogen sources include rainfall and applied water, resident soil minerals, crop residue decomposition, and fixation by certain crops. Varying concentrations of nitrogen and phosphorous compounds are found in agricultural drainage waters of the San Joaquin Valley.

Algal growth in the receiving waters is promoted by nutrients. Although the kind and amount of nutrients required for the numerous forms of algae are not completely understood at the present time, it is known that both nitrogen and phosphorus may at times be limiting growth factors. The general term "algal growth potential" (AGP) has been developed to encompass all the nutrients involved. Excessive nutrient enrichment can create a condition known as algae bloom, which, with the decay of dead algae, may produce tastes, odors, and in a few cases toxic materials which are injurious to plant and animal life.

Biological studies of the phytoplankton in the San Joaquin Valley's agricultural drainage waters were conducted from January 1962 to June 1963. The main areas of study were stations on the San Joaquin River. Plankton and chemical samples were analyzed weekly for 12 months in order to identify and determine the quantity of the genera of algae from the drainage area waters and predict the conditions under which toxic or nuisance blooms might be likely to occur. It was concluded that nuisance blooms of algae may be expected in the surface drainage facilities between April and September when nitrates, phosphates, and temperatures are relatively high. Whether algal blooms will appear in excessive numbers in the San Joaquin Valley drainage facilities will depend on the modes of operation and maintenance of the drainage facilities.

The analysis of pesticides from subsurface tile drainage showed that they were in the same general range as those found in ocean and bay waters. The Master Drain is planned to contain mostly subsurface tile drainage waters, therefore, pesticides are not expected to pose any significant problems.

Excluding nitrogen, it appears that there will not be any significant increases in the concentration of the constituents in the receiving water at the initial discharge location in the San Joaquin River near Antioch Bridge due to the discharge of the drainage facilities.

One of the main reasons why the constituents of the Master Drain, other than nitrogen, will have such a negligible effect on the receiving waters is that in the summer when the salt water intrusion in the receiving waters is generally maximal the quantity of flow in the Master Drain will be maximal, whereas in the winter when the salt water intrusion in the receiving waters is generally minimal, the quantity of flow in the Master Drain will be minimal.

The San Luis Drain is scheduled to be constructed in different phases that extend from the vicinity of Kettleman City to Antioch. Construction is scheduled to be completed in 1972. A discharge control reservoir will receive the initial flow of the upstream portion of the service area of the San Luis Drain until construction is completed to Antioch. After that it will be available as an emergency holding reservoir to be used in the event that the water of the San Luis Drain is of such quality that its discharge would be detrimental to the receiving waters during short periods of time. If unexpected long term problems should develop the discharge point of the Drain would be relocated.

The Department of Water Resources retained three consultants from the University of California to study and report on the feasibility of removing pesticides and AGP from the San Joaquin Valley's drainage waters. This group was known as the Biological Treatment Consulting Board. Basically its recommendations were to construct a prepilot plant in order to determine the feasibility of removing algal growth potential from the drainage waters and to establish design criteria so that two 1-million gallon per day pilot plants could be constructed. The two pilot plants should produce enough information to enable a decision to be made as to the large scale economic feasibility of removing algal growth potential from the drainage waters. The economics of treatment will be weighed against relocation and discharge to the ocean.

The Department, the Federal Water Pollution Control Administration and the Bureau of Reclamation joined in a three million dollar, three-year study in 1967 to determine the economics of nitrogen removal treatment. At the Agricultural Waste Water Treatment Center near Firebaugh studies are being conducted in algae stripping and bacteriological denitrification.

The Department of Water Resources and the U. S. Bureau of Reclamation have established a surveillance program to monitor representative stations on the Delta and Bay to obtain background information before the drainage facilities begin to discharge into the system and to detect possible changes in water quality of the receiving water after drain discharge begins.